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'ENGLISH ELECTRIC' straightflow valves are manufactured for all diameters and heads, and their robust spherical form makes them particularly suitable for high pressures. Illustrated is one of five 11 ft. straightflow valves — probably the largest in the world — now in service in Portugal.

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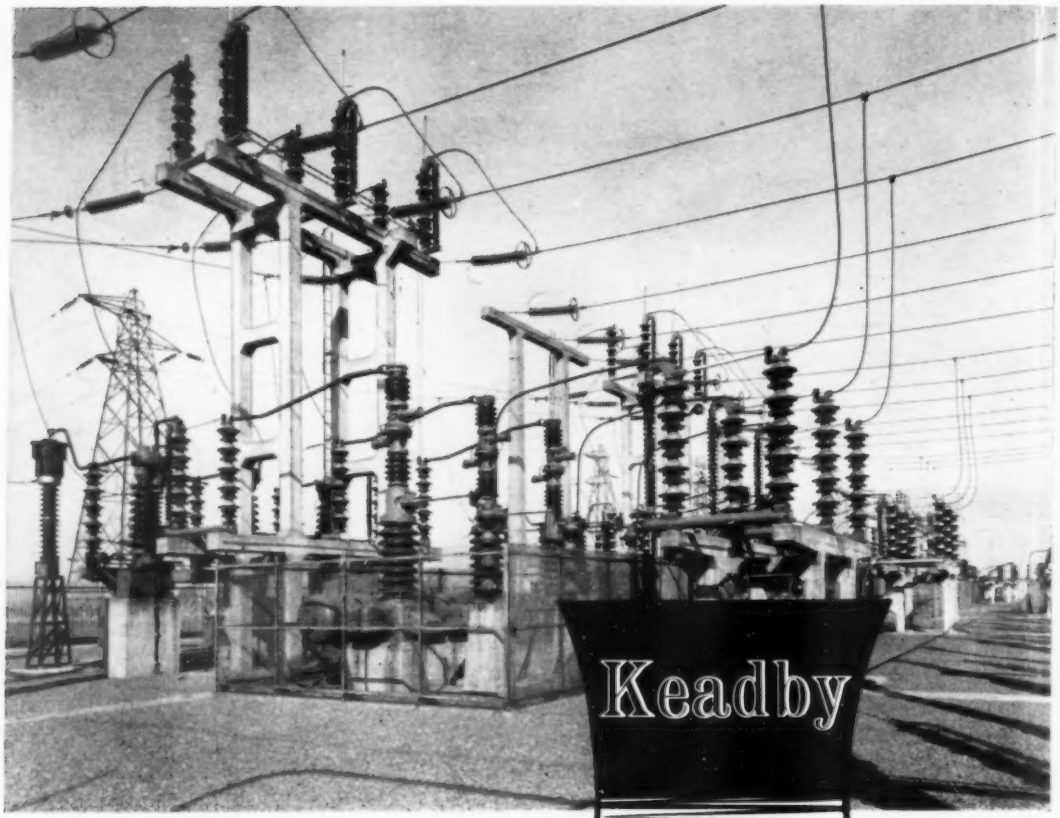

Keadby power station

Photograph by courtesy of the C.E.A. Yorkshire Division

Consulting Engineers : Ewbank & Partners

The 132-kV generator and transmission circuits of Keadby Power-Station are controlled by Reyrolle 2,500-MVA air-blast circuit-breakers.

A number of the transmission lines are also protected by means of Reyrolle Telephase carrier-current protection.

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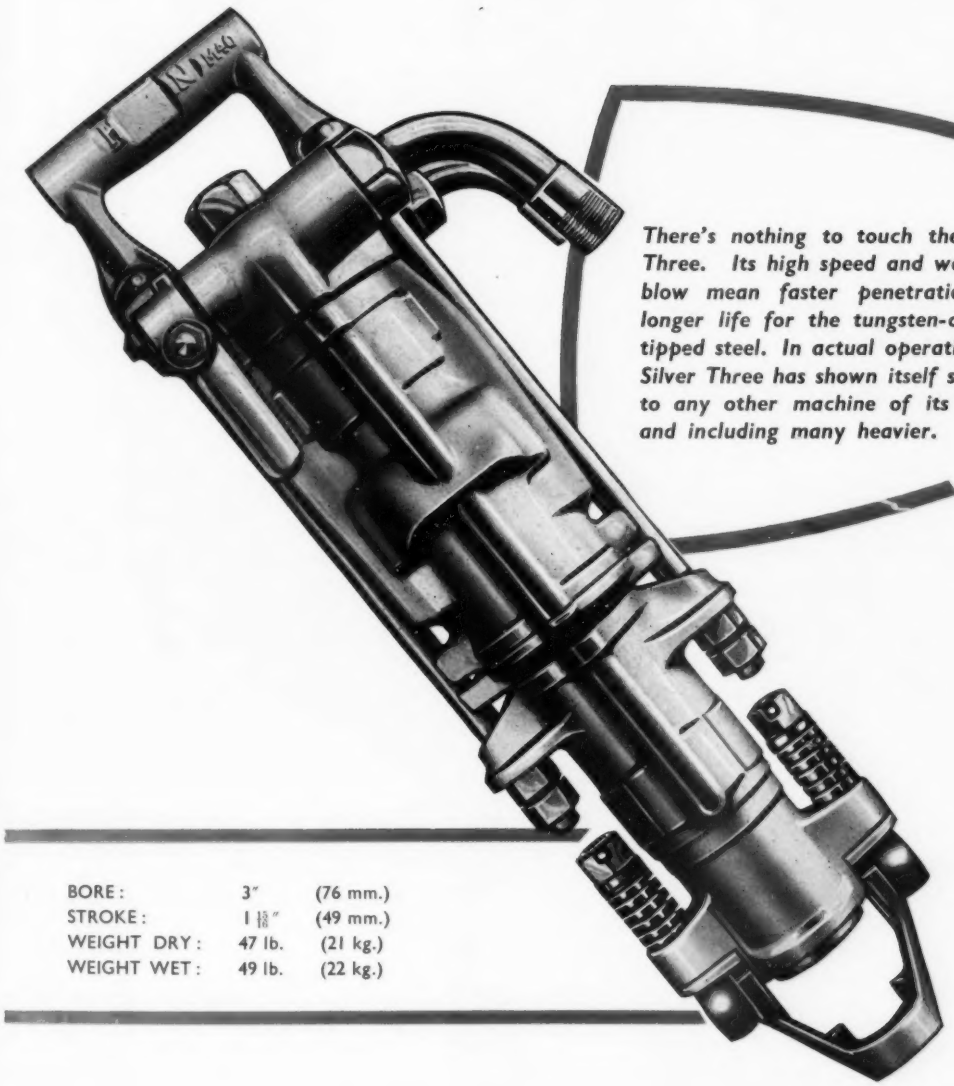

There's nothing to touch the Silver Three. Its high speed and weight of blow mean faster penetration and longer life for the tungsten-carbide-tipped steel. In actual operation, the Silver Three has shown itself superior to any other machine of its weight and including many heavier.

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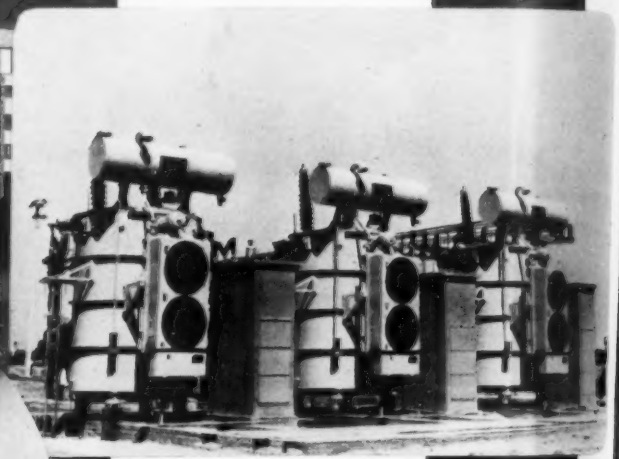

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New Zealand Government photograph

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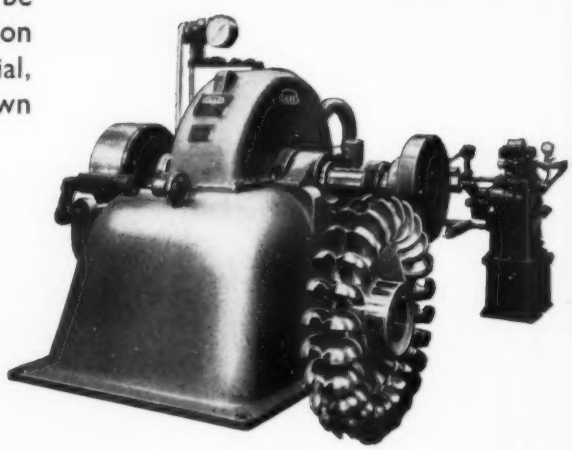

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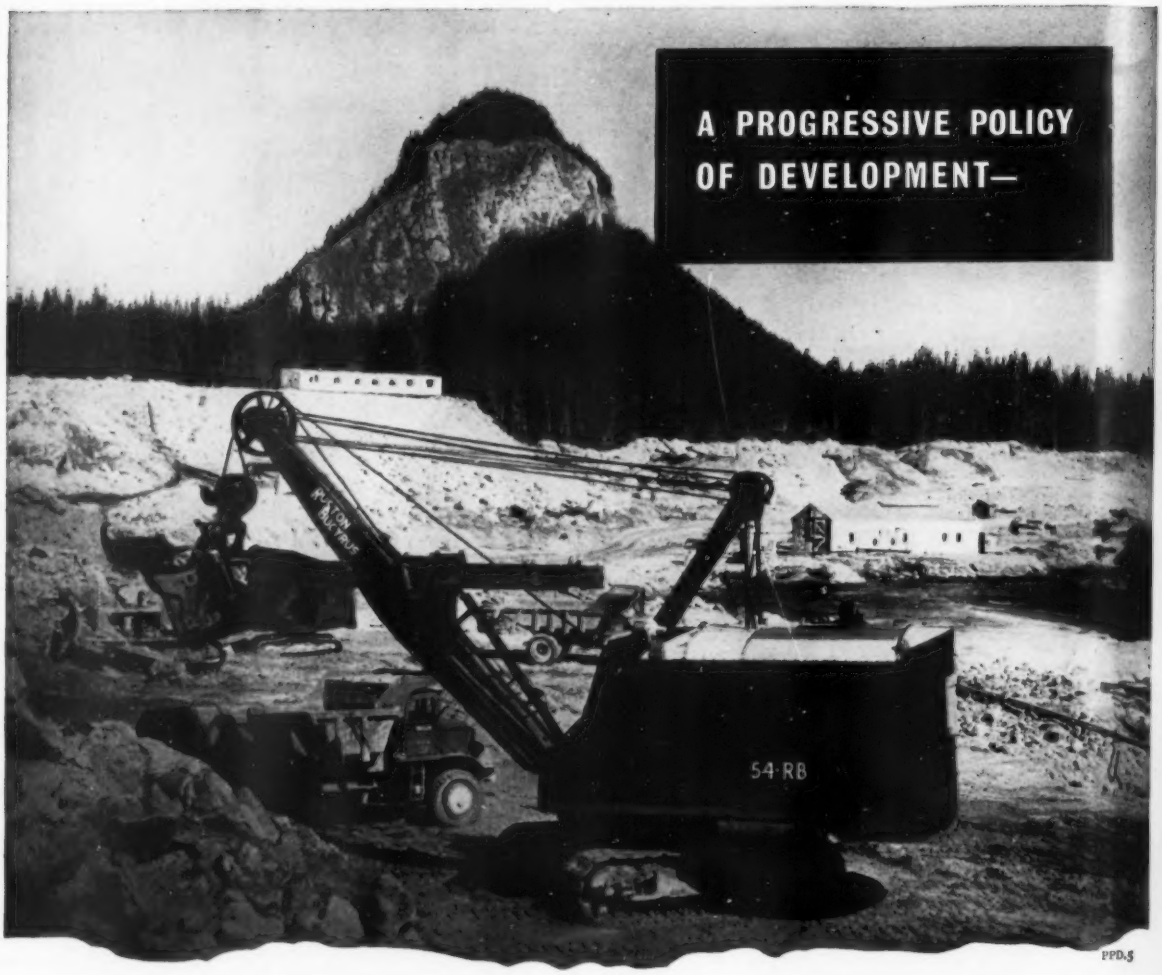

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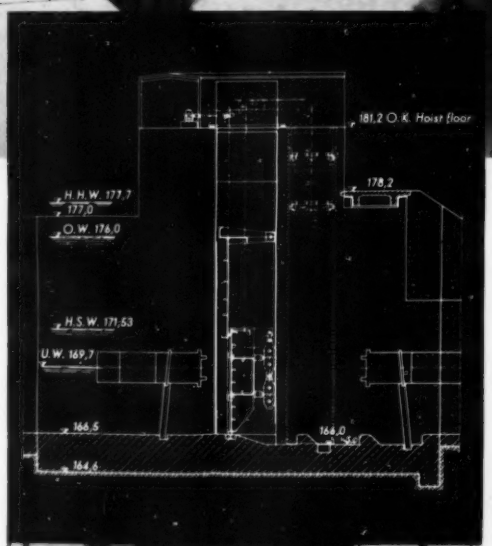
Downstream gate of Besigheim lock two-part lifting gate with counterweight compensation



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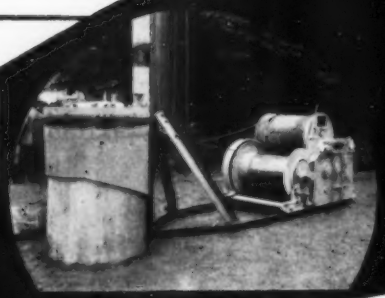

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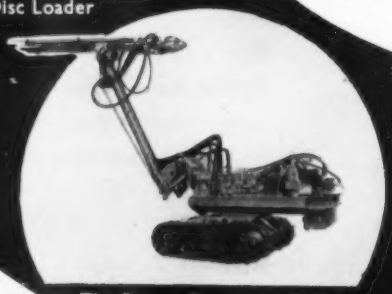

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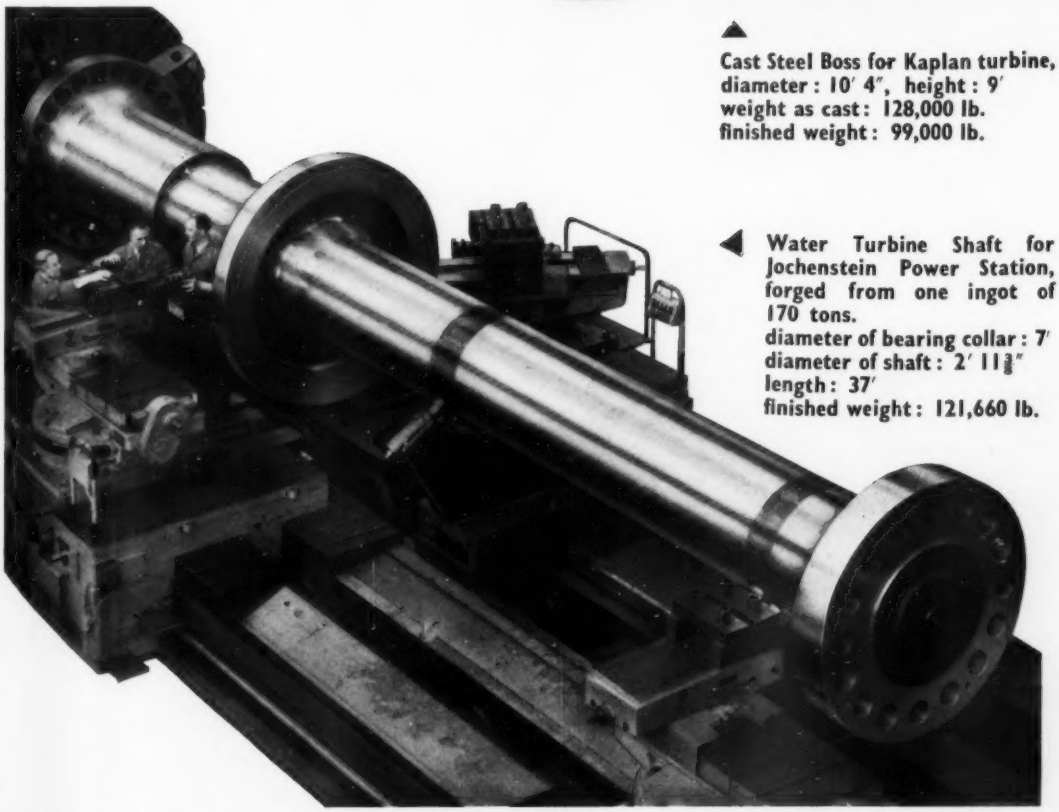

◀ Water Turbine Shaft for Jochenstein Power Station, forged from one ingot of 170 tons.
diameter of bearing collar: 7′
diameter of shaft: 2′ 11⅜″
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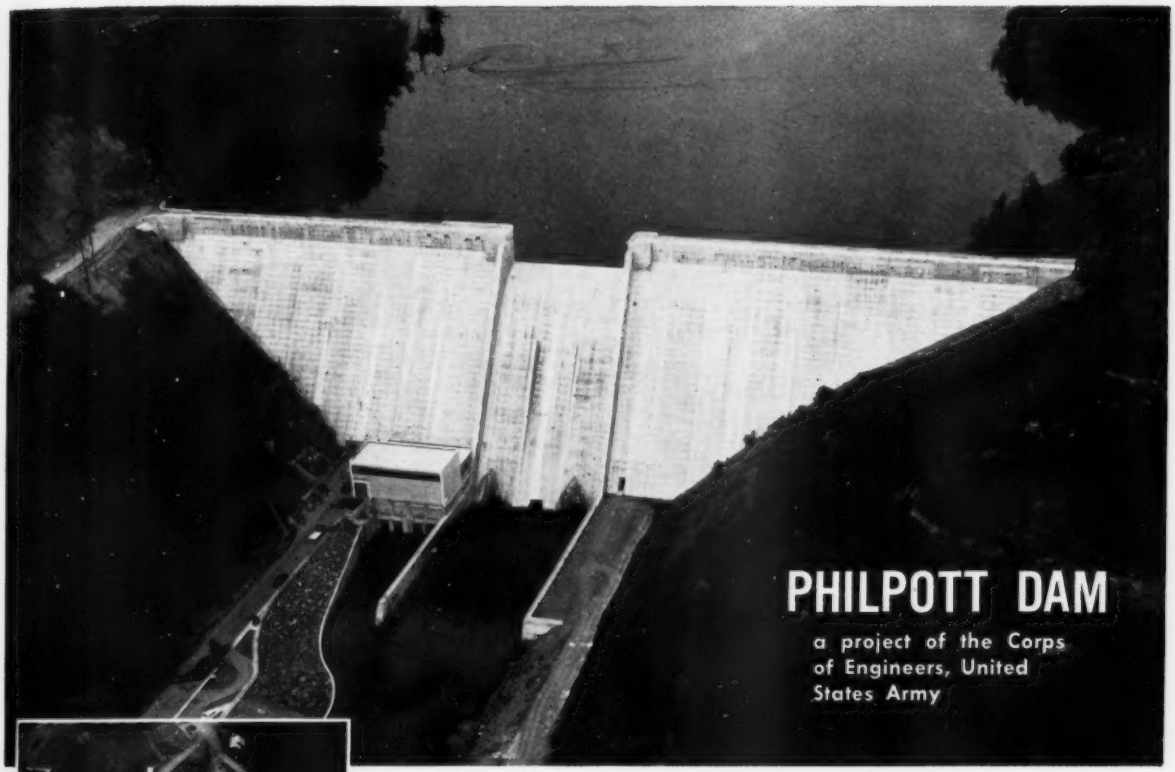

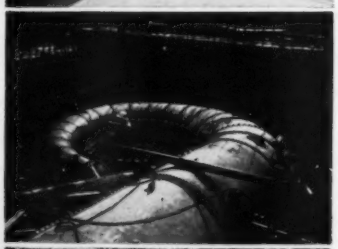

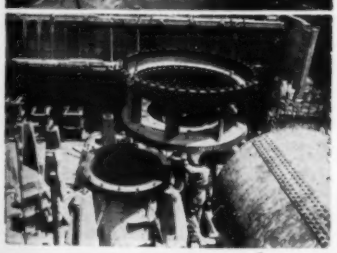

Another Outstanding Installation of **Leffel Hydraulic Turbines**

Philpott Dam, a recent Corps of Engineers, United States Army, project on the Smith River in Henry and Franklin Counties, Virginia, is a site of another outstanding installation of efficient dependable Leffel turbines. The Philpott project was constructed for flood control and hydroelectric power generation. It is one unit of a comprehensive reservoir system planned for the Roanoke River basin.

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The view above shows the completed project. The views at the left show the project under construction, the spiral casing for one turbine in place, and a stay ring being lowered into place over the draft tube.

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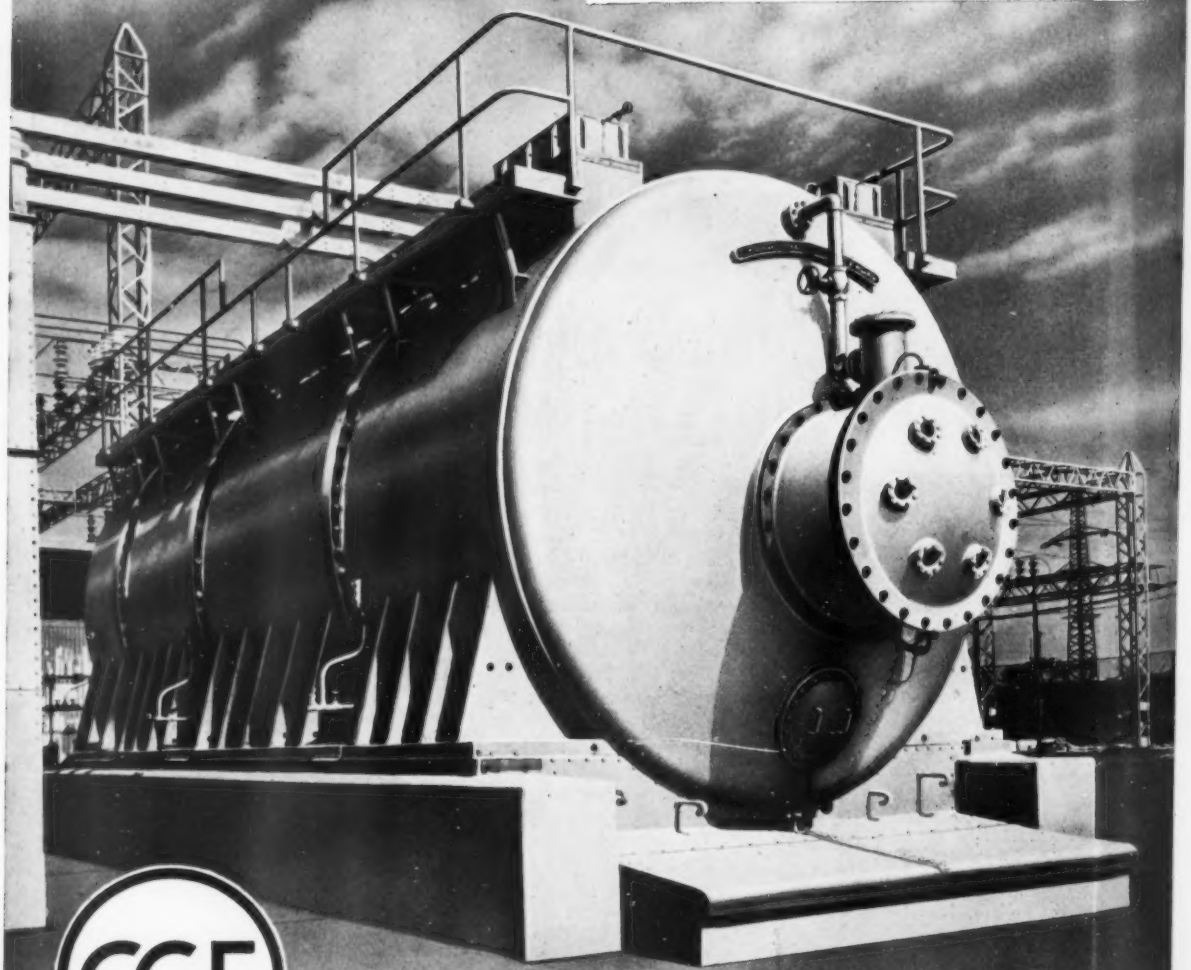

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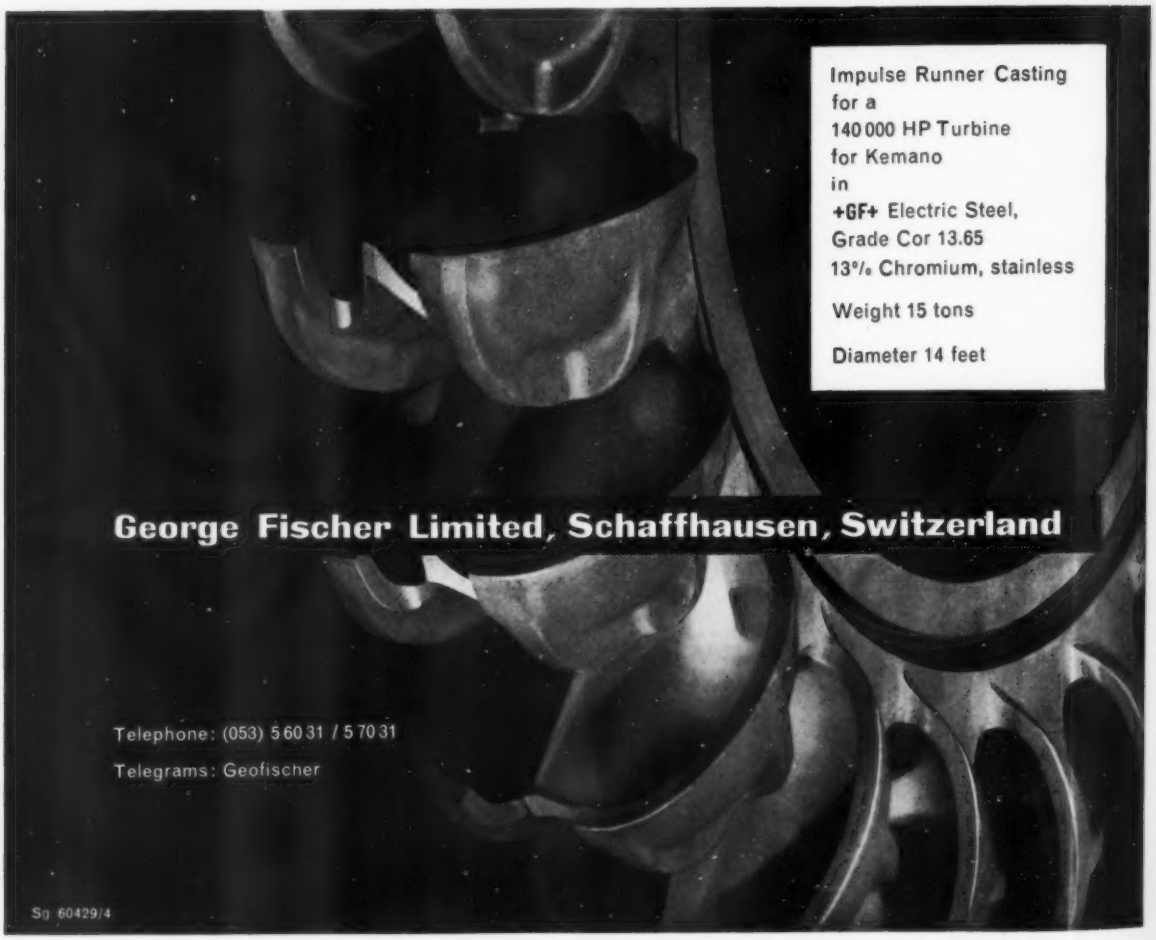

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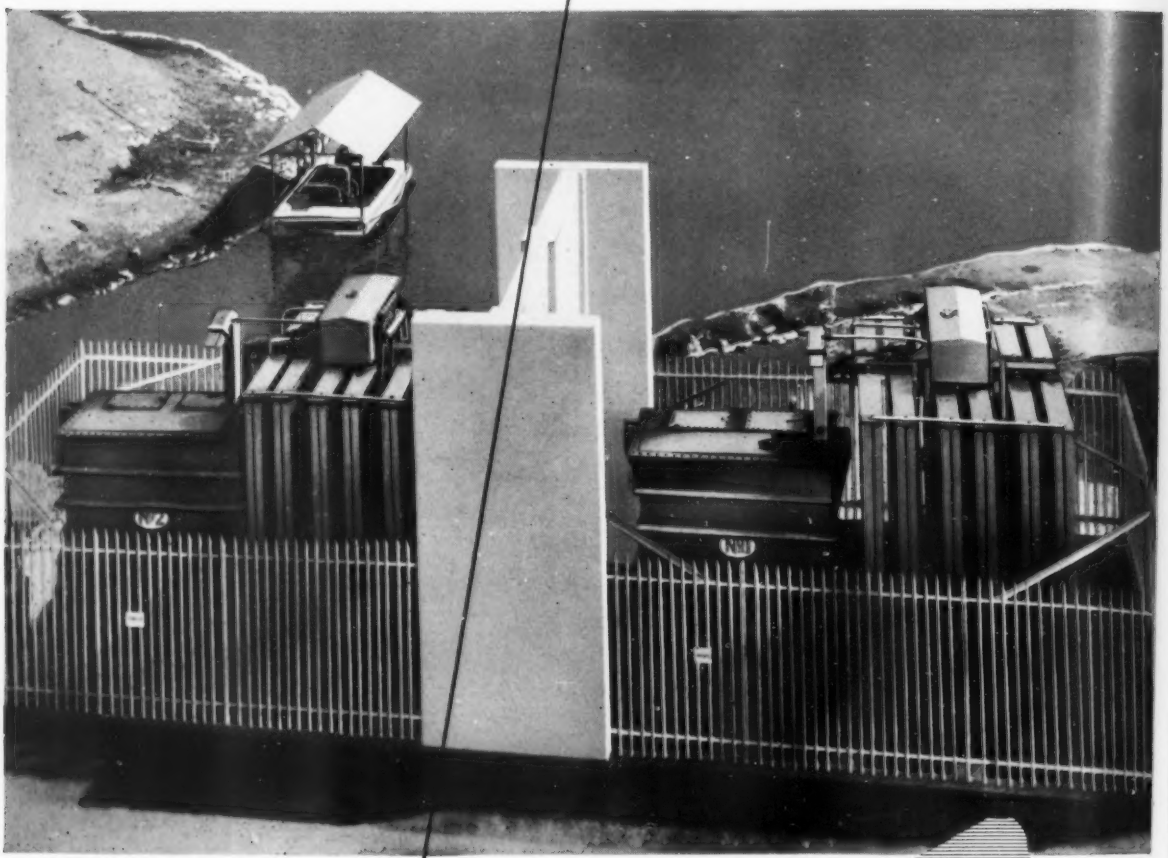

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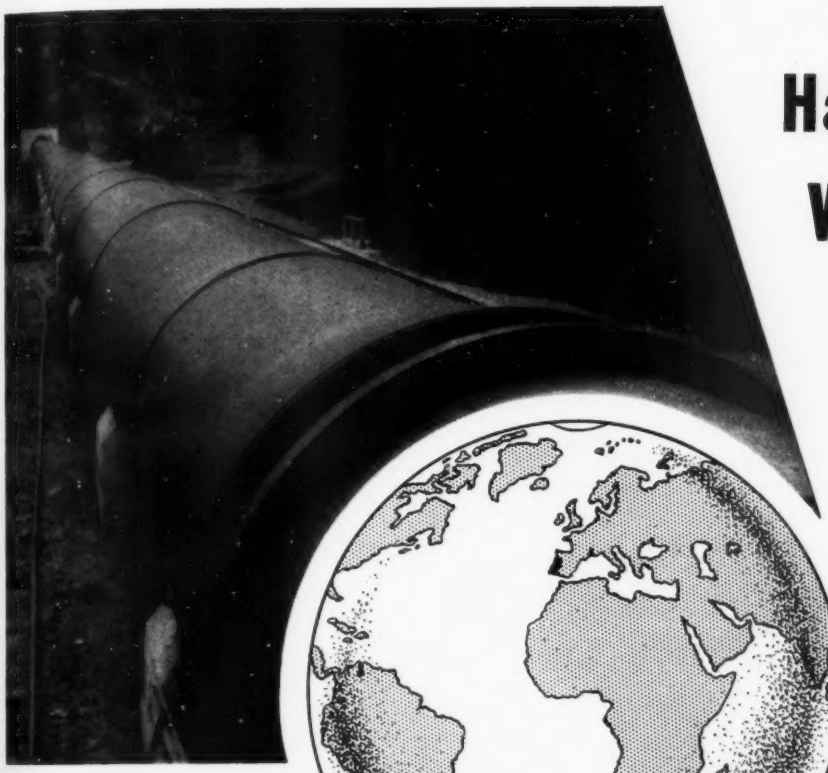

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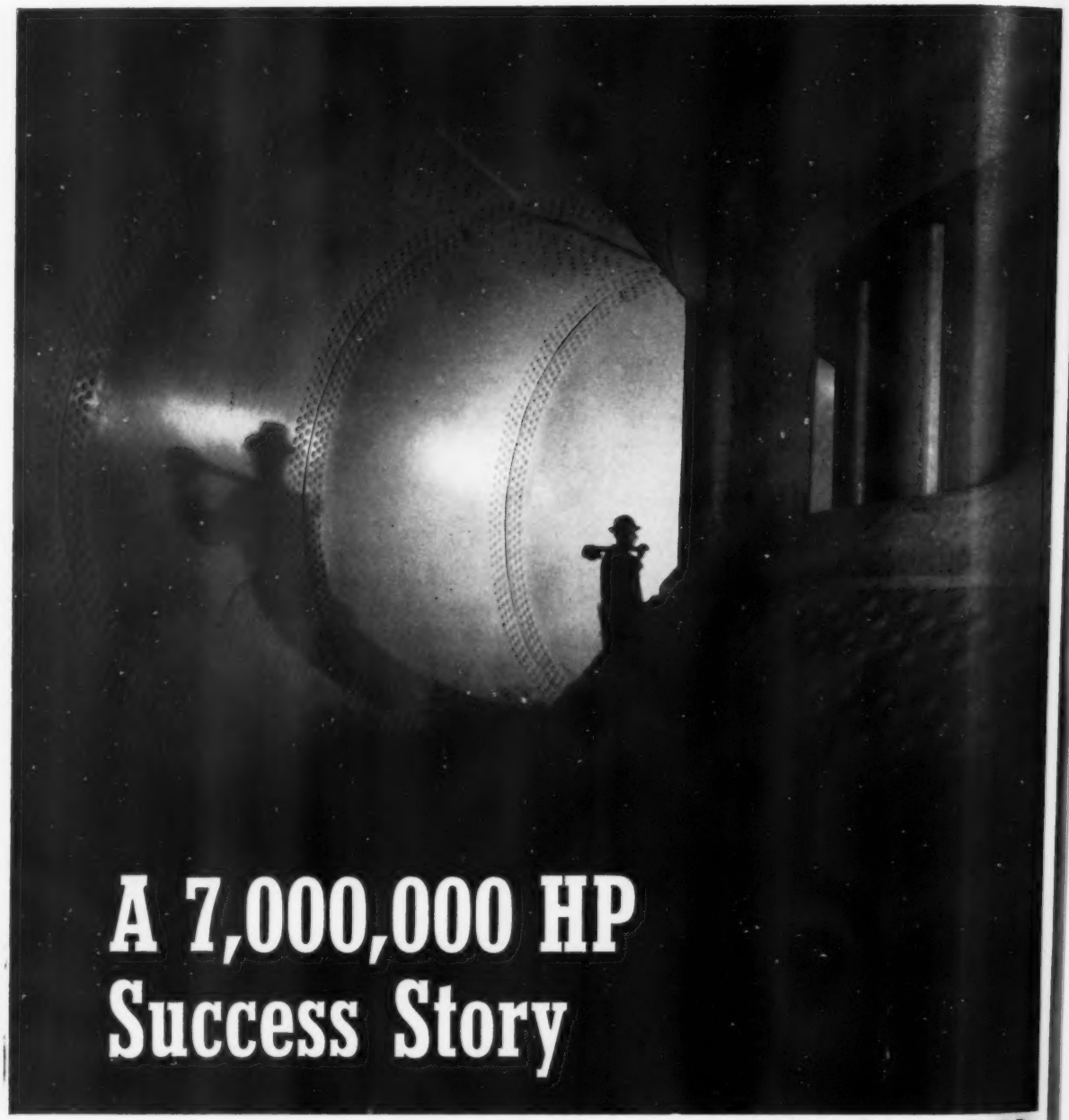

A 7,000,000 HP Success Story

Interior view of spiral casing at Norris Dam

Achievements of Newport News personnel in designing and building water power equipment during the past thirty years reflect a high integration of skill and production facilities.

Answering demands for hydraulic turbines rated as high as 165,000 horsepower and as low as 500 horsepower, this trained organization has successfully filled contracts with an aggregate rated output in excess of 7,000,000 horsepower.

Other essential equipment including penstocks, spiral casings, valves, pumps, gates and rack rakes are also designed and built by Newport News.

An illustrated copy of our booklet entitled, "WATER POWER EQUIPMENT," will be sent to you upon request.

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S.P.P. Post Insulators

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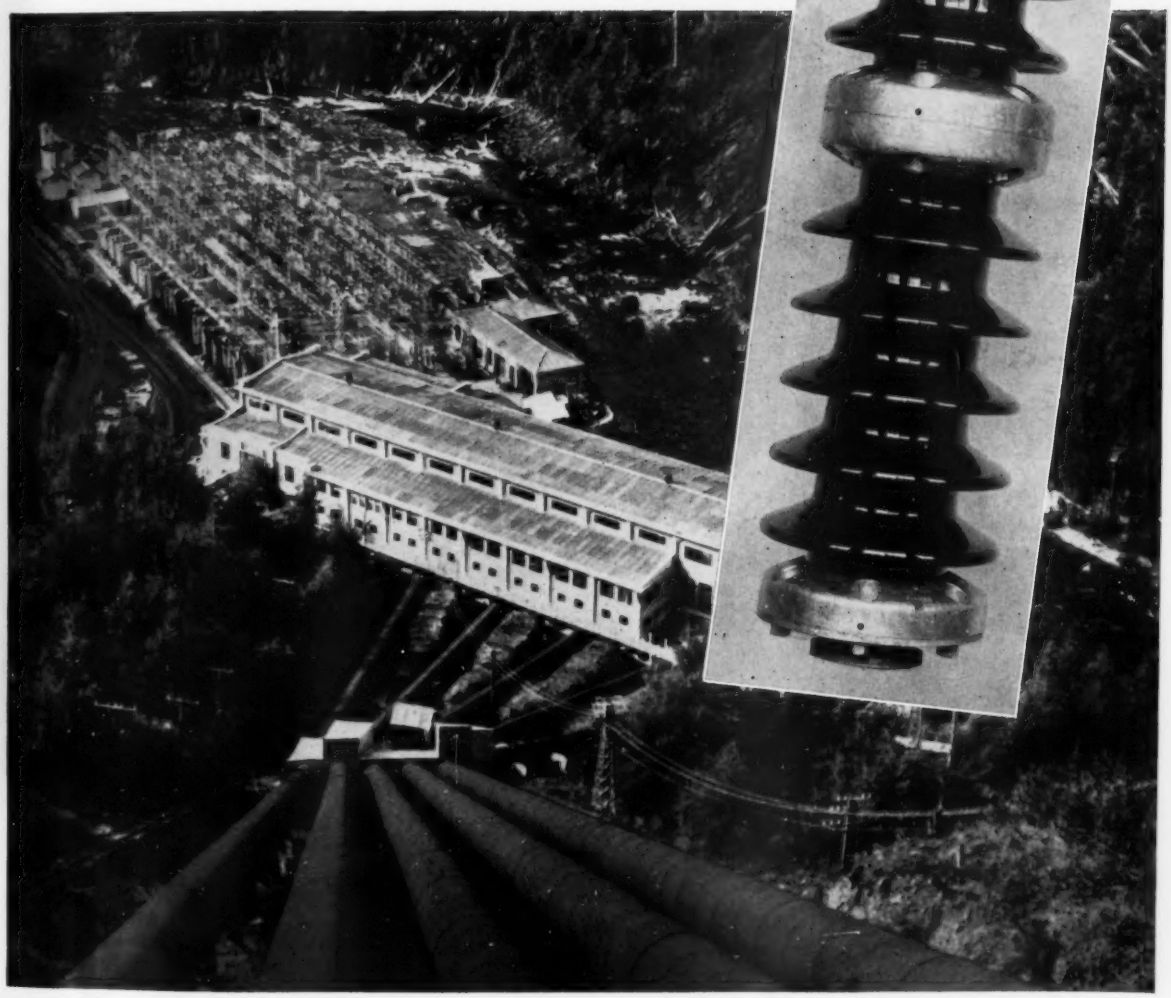
Tarraleah Sub-Station, Tasmania



The Sub-station at Tarraleah, Tasmania, is one of the many 110 kV. and 88 kV. sub-stations on the Hydro-Electric Commission's system equipped throughout with S.P.P. Cylindrical Post Insulators.

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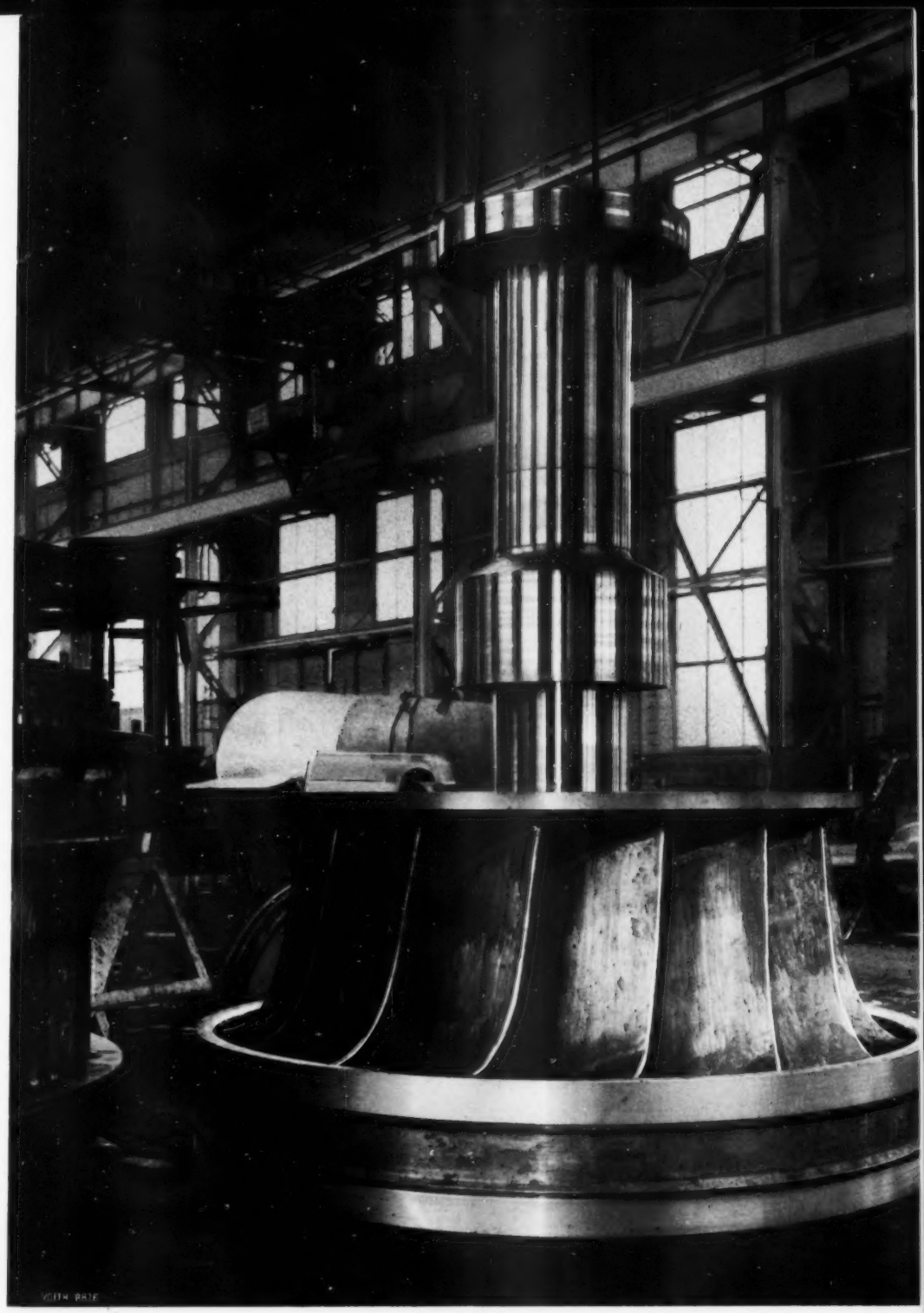

20,000,000 H.P. delivered by some 16,000 **VOITH** TURBINES

An example of a VOITH delivery: 2 Francis Spiral Turbines, 34,000 H.P. each under a head of 184 feet, for the Bouçã Power Station, Portugal.

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of the potteries, the bottle kiln, is becoming as much a 'period piece' as Arnold Bennett's novels of the 'Five Towns'.

In the new factories, the smoke and smother are replaced by the tunnel kiln fired by gas or electricity and the ancient art and science of pottery takes place in clean, efficient and well lit workshops.

It is significant that the foundations for these conditions were laid over eighty eight years ago when Taylor the engineer collaborated with Tunnicliff the potter to produce precision porcelains. The wheel has come full circle, for it is these very porcelains that have played so vital a part in the electrical development making today's conditions possible.

It is significant that this alliance of engineering knowledge with the science and art of the potter, is still the mainspring of the vitality of the Company known all over the world as Taylor, Tunnicliff—masters of porcelain insulation.

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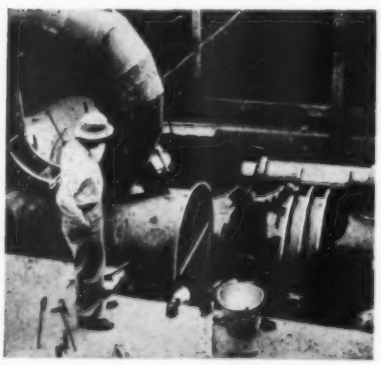
SMS-Kaplan Turbines Help Harness Rio Grande for Brazil

The Itutinga Project With Two 17,000 HP Units Provides Bulk Power For The Southern Part Of The State Of Minas Gerais, Brazil

Situated on Brazil's upper Rio Grande River 150 miles northwest of Rio de Janeiro, the Itutinga Falls Plant is now delivering power. The first phase of this project consists of two 12,000-kilowatt generating units, powered by SMS-Kaplan turbines. Foundations for a third unit have been poured and provision made for a fourth unit at some future date.

Work at Itutinga was begun late in 1952 and the first generating unit went on the line in March, 1955. The second unit was completed and put in operation in July, 1955.

Here the 6-bladed runner with the inner head cover and shaft is being moved into position for final assembly. The cast steel runner blades are protected with stainless steel to minimize the pitting from possible cavitation. The turbine shaft bearing is of the self-lubricated type.



Initial assembly of the station service unit shows the welded plate steel spiral case being aligned with a manually-operated SMS-Butterfly valve. This turbine inlet valve, 48 inches in diameter, is equipped with a rubber seal on the disc to provide tight shut-off. Both valve disc and body are welded plate steel construction.

INSTALLATION DETAILS

As shown in the accompanying sketch, the earth dam is extended by a concrete spillway section containing five 20-foot high by 34.5-foot wide taintor gates, designed by SMS. The taintor gates are operated by 30-ton twin drum, flat cable hoists, also designed and manufactured by SMS.

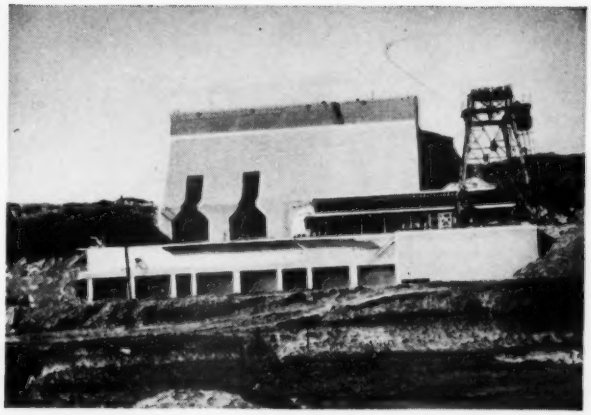
Adjacent to the forebay intake, an SMS skimmer gate and manual hoist built by us are installed to bypass floating debris diverted by a floating log boom. An 8-foot, motor-operated SMS-Leonard trash rake cleans the intake trash racks.

The turbine intakes, at the downstream end of the forebay, are provided with SMS fixed wheel, penstock intake gates operated by 15-ton monorail hoists. The intake to the station service unit is also protected by a 5-foot square SMS intake gate with motor-operated screw stem hoist. Near the bottom of the intake canal one SMS sliding gate with hoist serves as a sand sluice. The remaining hydraulic accessories furnished by SMS include two draft tube gates and three filler gates with hoists for the turbine intake penstocks.

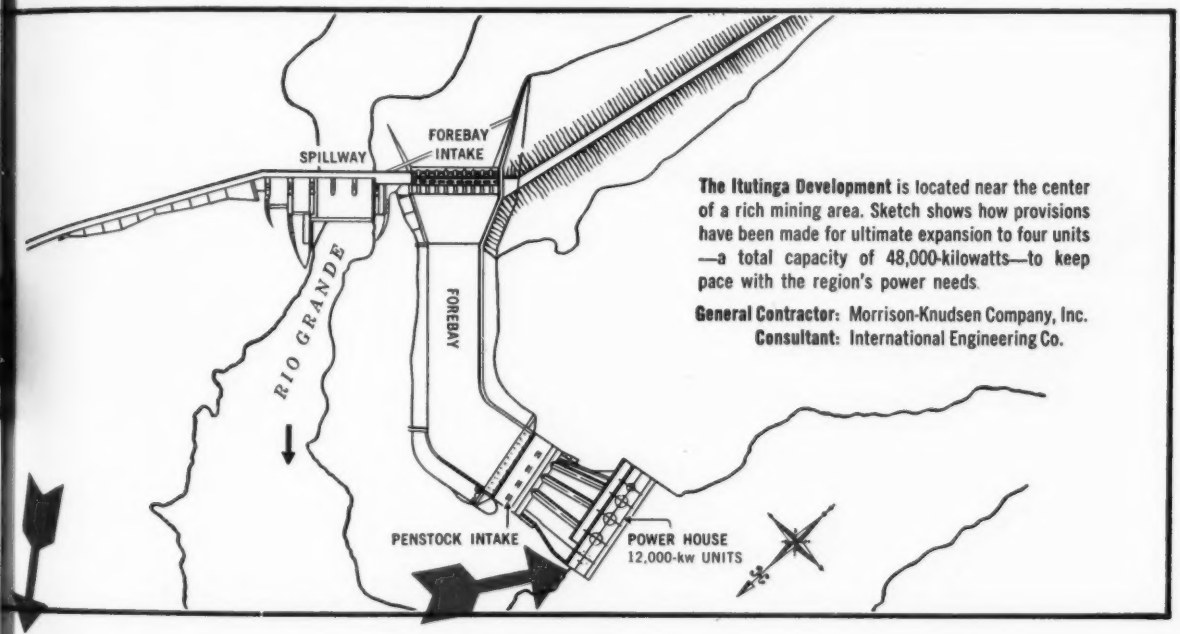
TURBINES

Each of the two SMS-Kaplan turbines is rated at 17,000 HP and operates at a synchronous speed of 225 RPM under a net head of 97 feet. The water is guided into the runners by 13-foot diameter, field-riveted spiral casings. In addition to the main units, there is a horizontal SMS-Francis turbine rated at 1,075 HP used for station service. The casing for this station service unit is welded plate steel.

The lower half of one of the fixed wheel turbine intake gates is being lowered into position prior to final assembly with the upper section.



From the downstream side of the powerhouse and forebay, the openings for future units and the Gantry Crane for handling the turbine and generator parts for this outdoor station can be readily seen.



The Itutinga Development is located near the center of a rich mining area. Sketch shows how provisions have been made for ultimate expansion to four units —a total capacity of 48,000-kilowatts—to keep pace with the region's power needs.

General Contractor: Morrison-Knudsen Company, Inc.
Consultant: International Engineering Co.

It is indicative of good selection and operation that the third and fourth turbines are to be added to the Itutinga Power House by SMS. The newest units, of the same physical size, are each rated at 20,000 HP under the original 97-foot head. They are of the Smith-Propeller, fixed blade type, and will carry the base load. Regulating will be done by the present Smith-Kaplan turbines. For information, write S. Morgan Smith Co., York, Pennsylvania, U. S. A.

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Licensees: The Harland Engineering Company, Ltd., Alloa, Scotland
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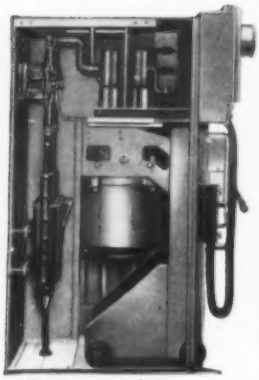
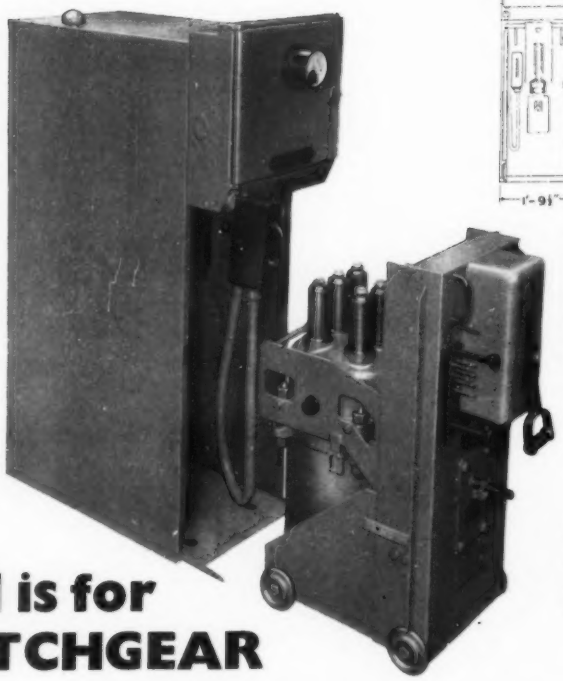
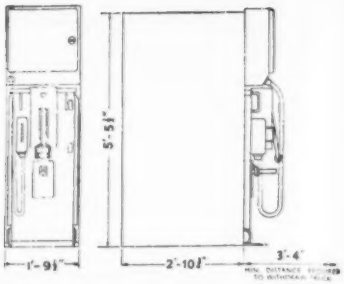


The interior of the 'BV' Unit





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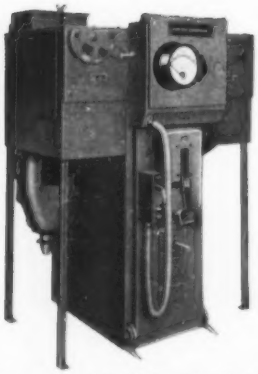

BV switchgear is designed for extension to small or other switch units/isolators as required. The illustration shows a BV unit combined with a type IB isolator.

Typical 'BV' Switchboard with spring-operated mechanism

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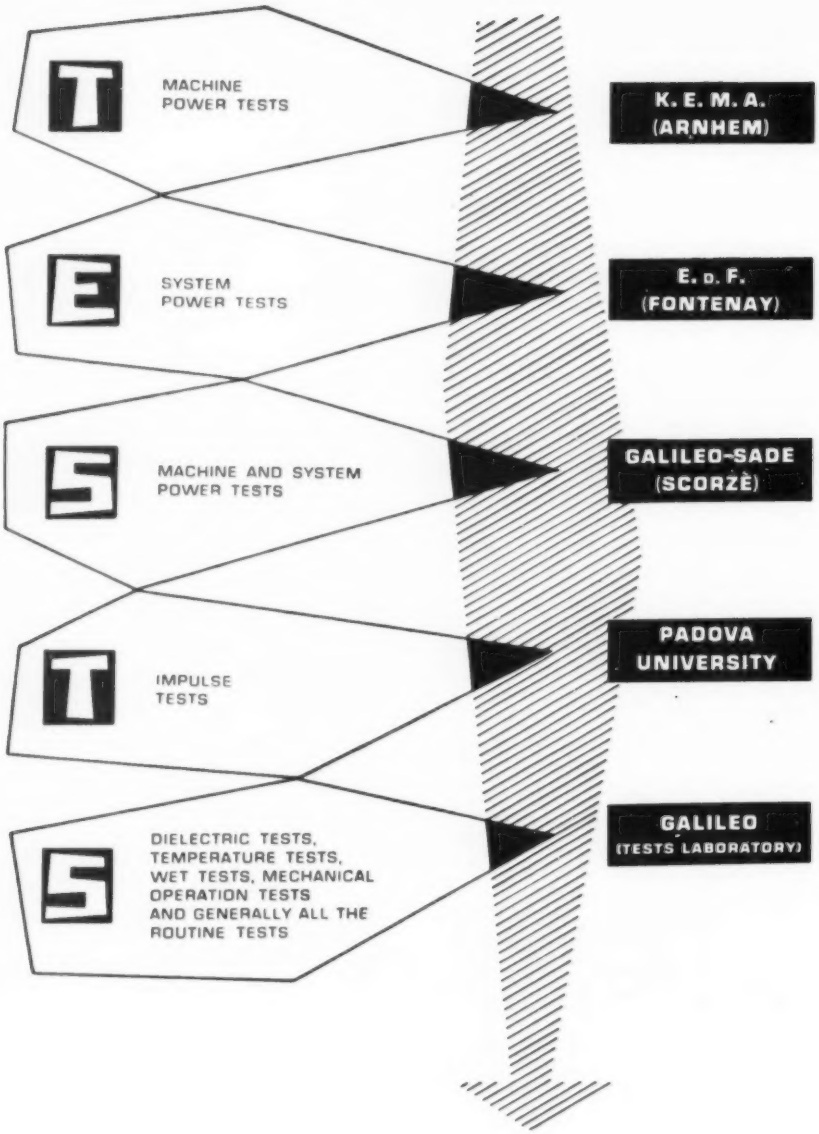

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ISOLATING SWITCHES - BUSHING INSULATORS - CONTROL SLABS PANELS
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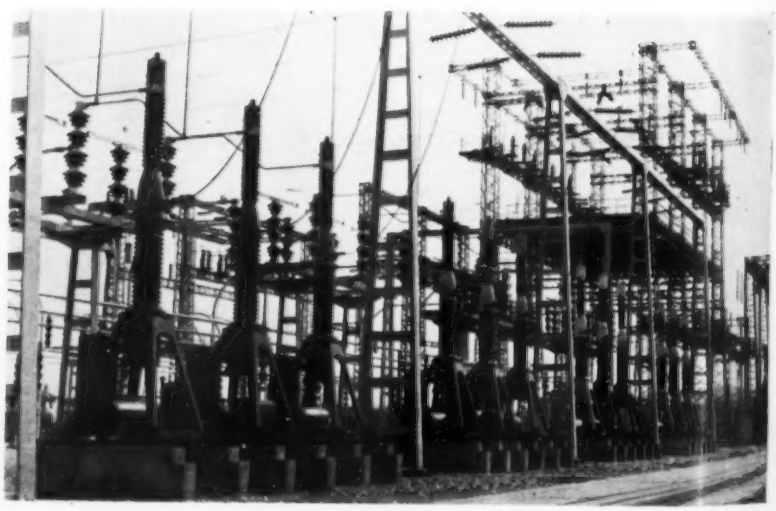
One French station of the Electricite de France equipped with Galileo Circuit Breakers for 150 kV.



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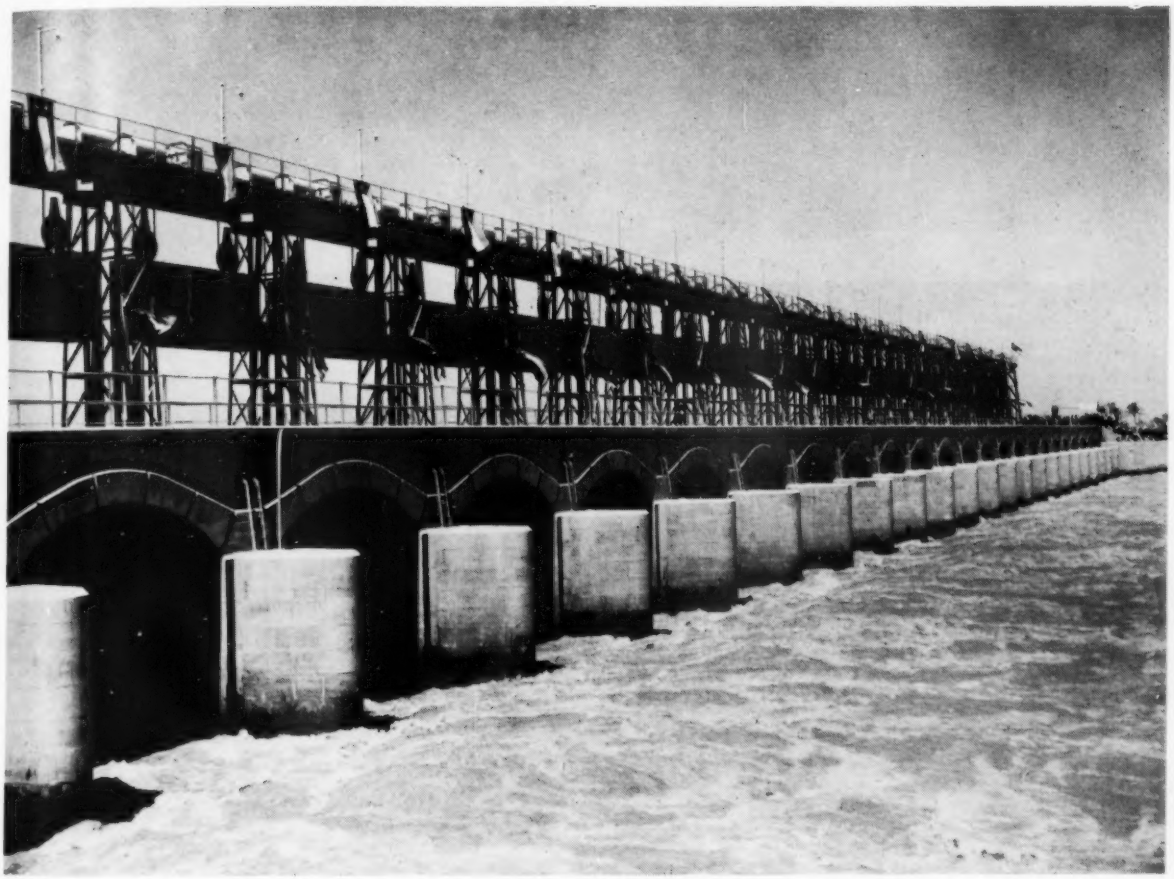

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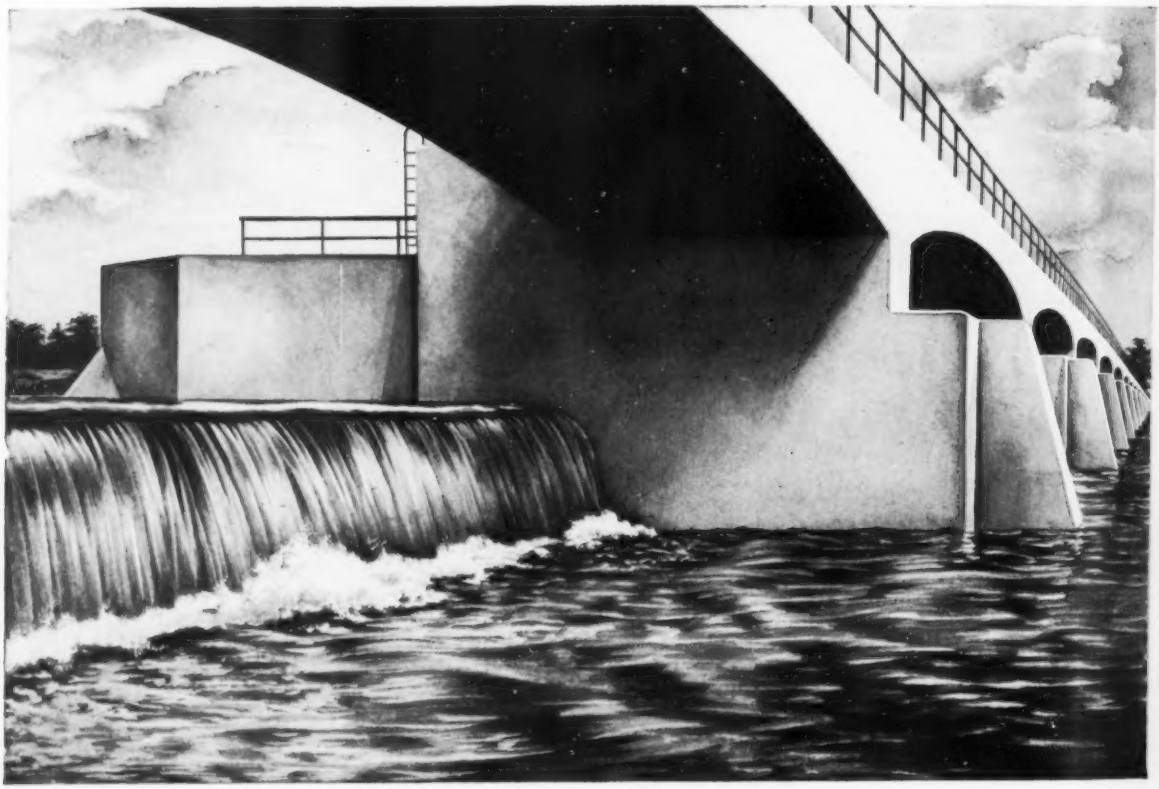

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Equipment of HITACHI

for Substation Service

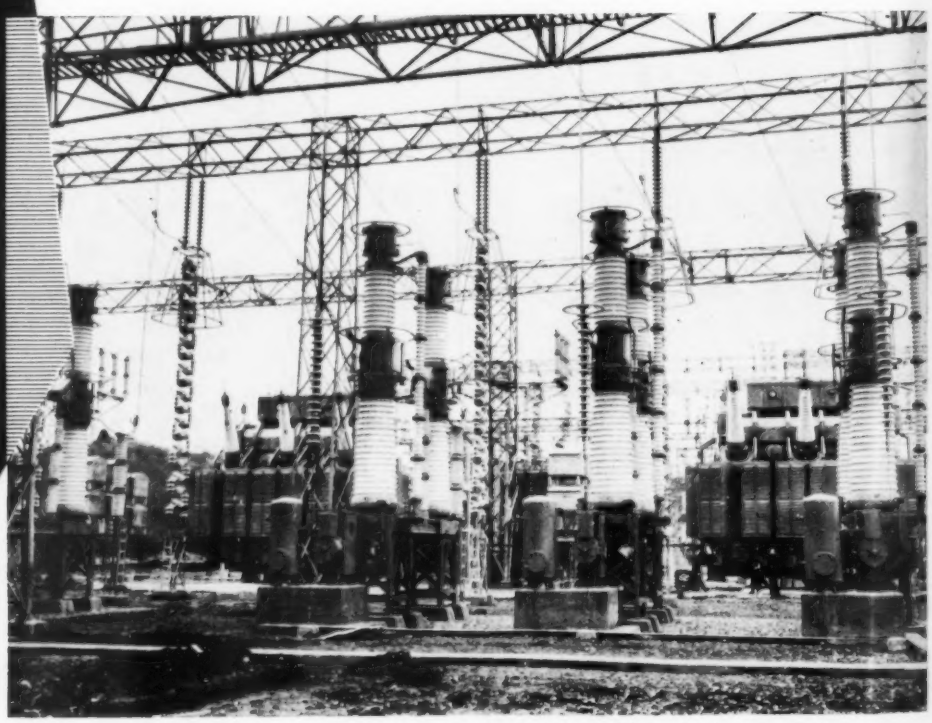
The photo shows Hitachi's 156,000 kVA super high voltage transformers in service at the Nishi Tokyo Substation of the Electric Power Development Co. These outdoor type transformers are of 3-phase, 3-winding, core type, forced oil and air-cooled system. The high and medium voltage winding of these transformers is provided with a Hitachi patent controsurge winding to increase their series electrostatic capacity and improve impulse voltage characteristics.

Rated output (Equivalent, 156,000 kVA)
- First .....120,000 kVA
- Second .....132,000 kVA
- Third .....60,000 kVA

Frequency .....50 cycles

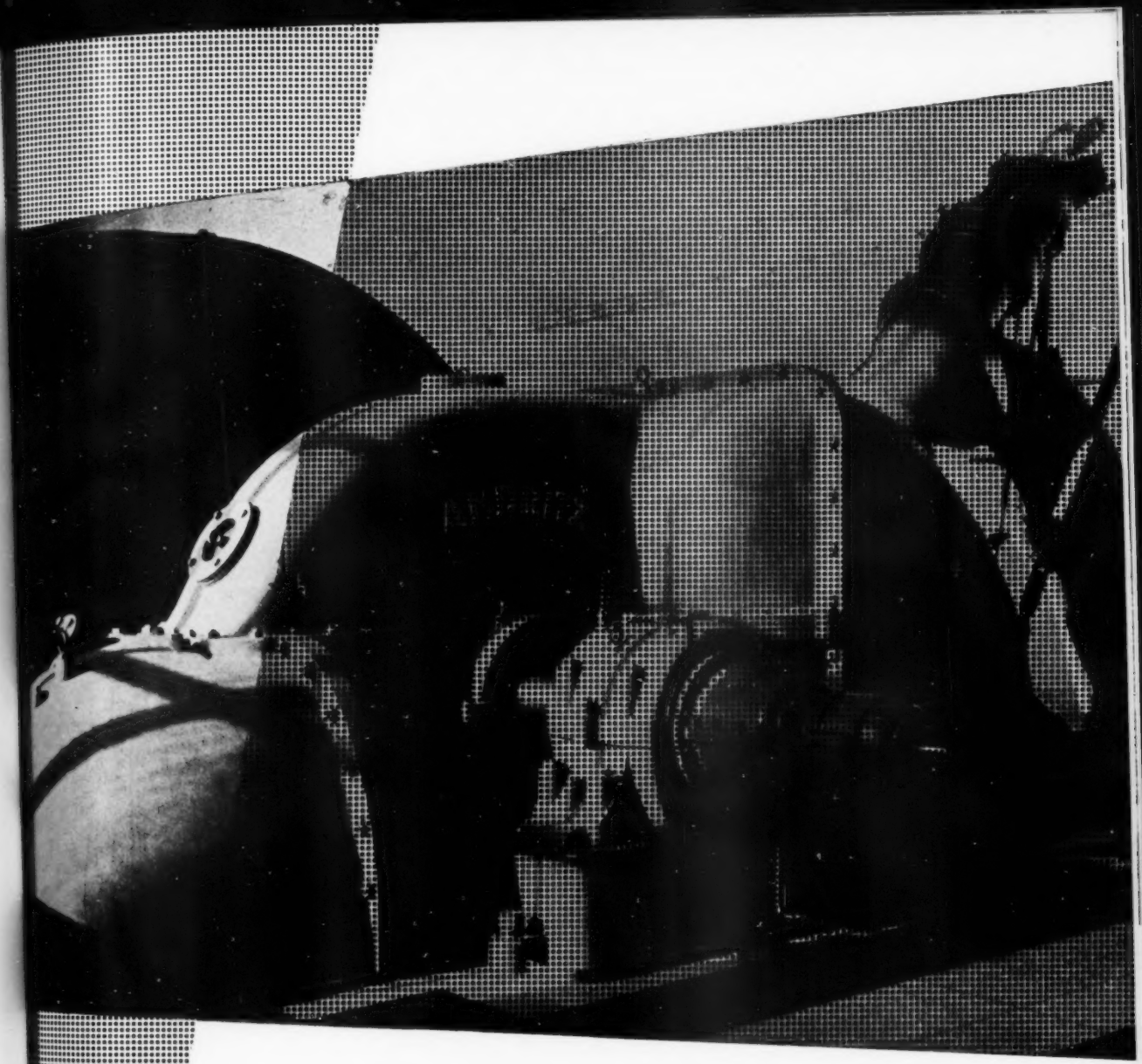
Voltage
- Primary.....F275-R262.5-F250 kV
- Secondary.....147,000 V
- Tertiary..... 12,600 V

Shown with these transformers are the circuit breakers of the Hitachi Contrarc type. Designed as the self-extinguishing type, they have also a forced extinguishing mechanism, which insures the constancy of the interrupting characteristic regardless of the magnitude of the interrupting current. It is another feature of these apparatus that by the use of the four-point simultaneous interrupting device, small currents such as charging current, exciting current, etc. can be interrupted positively. Also, an oil current extinguishing system which works on compressed air is used. This eliminates re-ignition completely.



Hitachi's 156,000 kVA super high voltage transformer and circuit breaker of the Hitachi Contrarc type

Hitachi, Ltd.
Tokyo Japan
Cable Address: "HITACHY" TOKYO



Water Turbines

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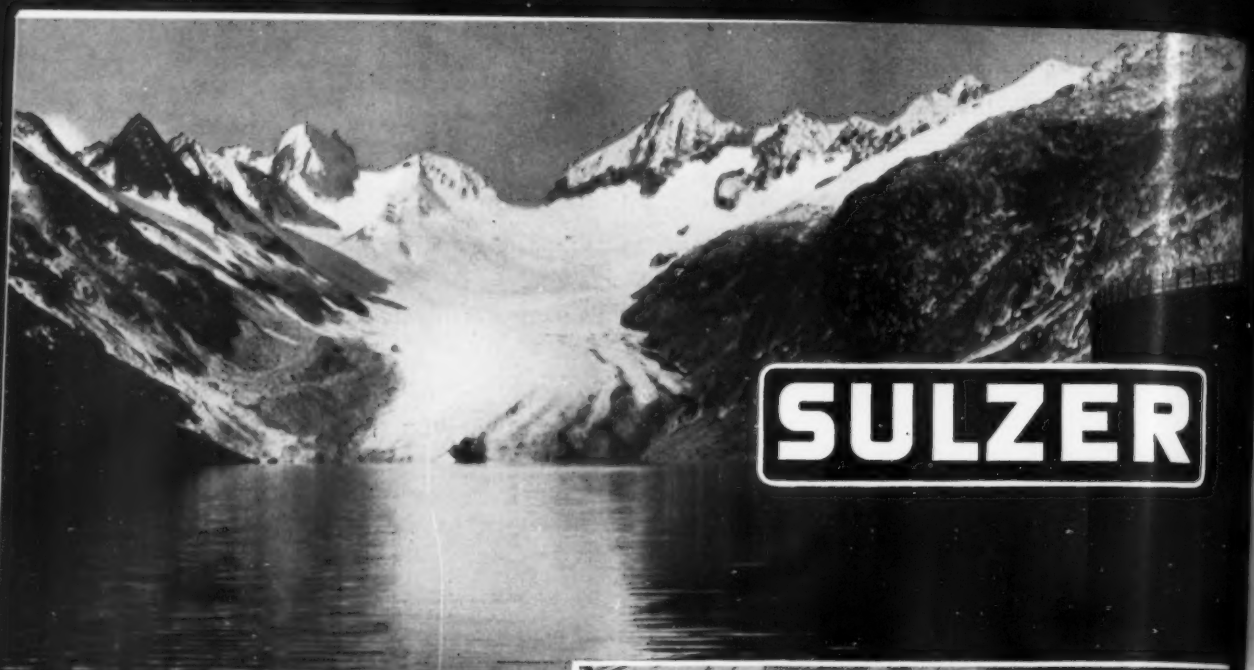

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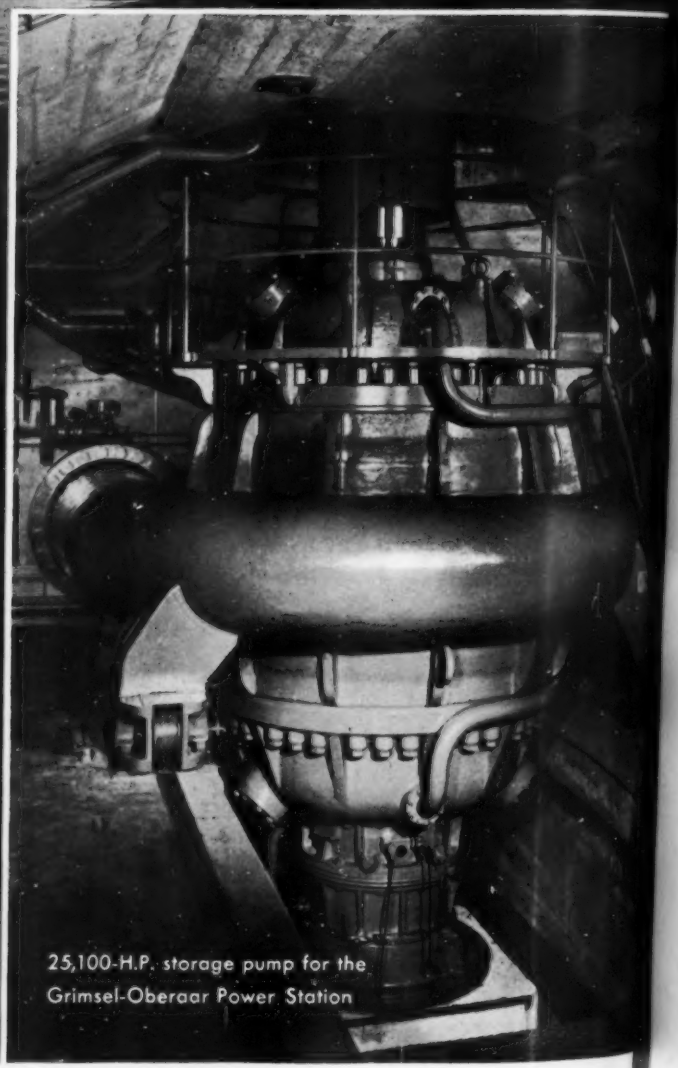
one pump for
Lünersee Power Station, Austria
(discharge 49,250 g. p. m., head 3,182 ft., speed 750 r. p. m., input 54,750 H. P.)

one pump for
Motec Power Station, Switzerland
(discharge 43,050 g. p. m., head 2,060 ft., speed 750 r. p. m., input 30,400 H. P.)

Lake Oberaar, 7,550 ft. above sea level, in the Bernese Oberland, Switzerland



25,100-H.P. storage pump for the Grimsel-Oberaar Power Station

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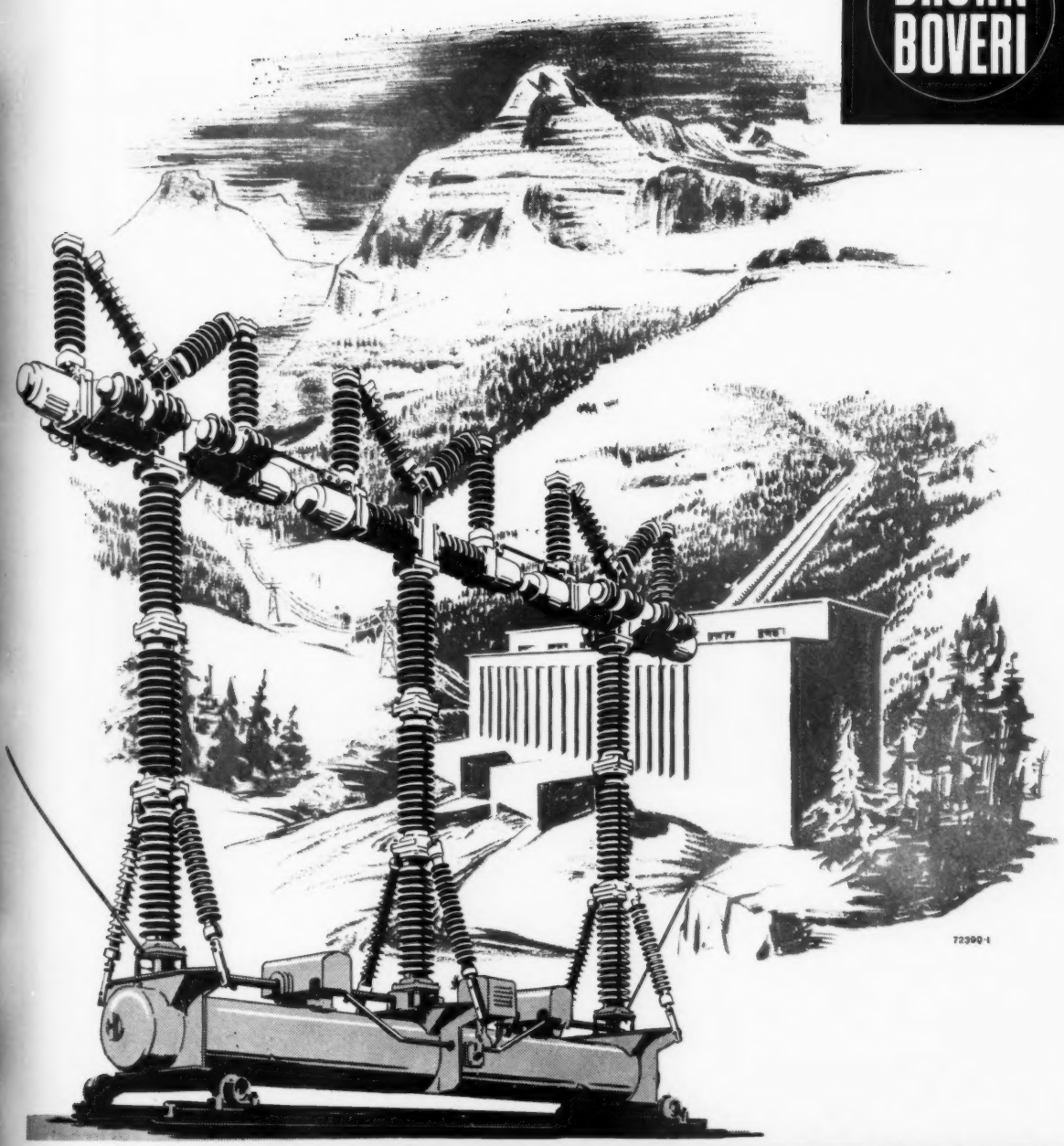

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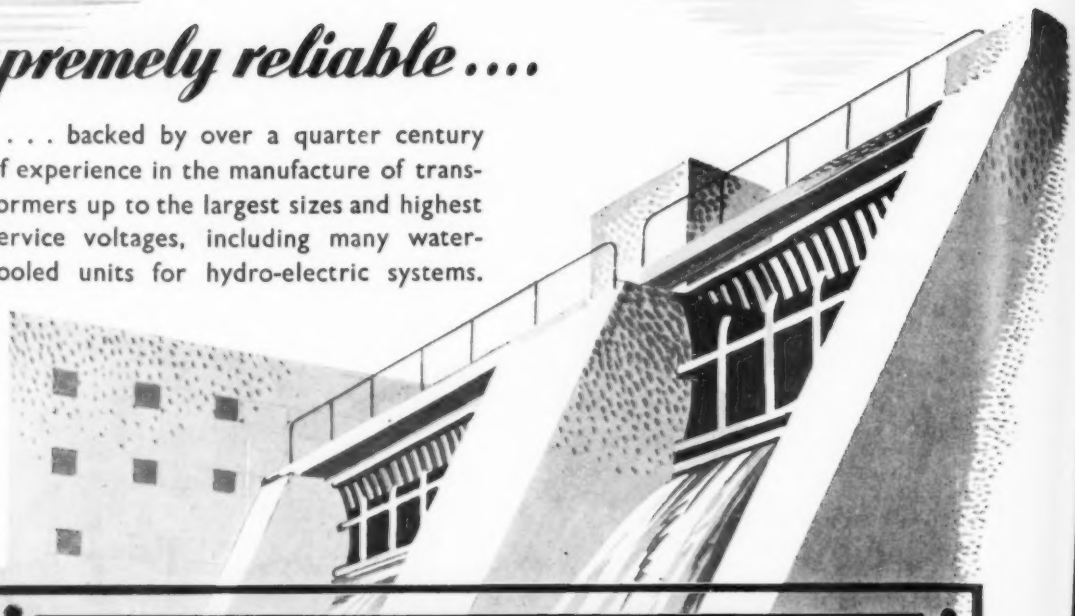

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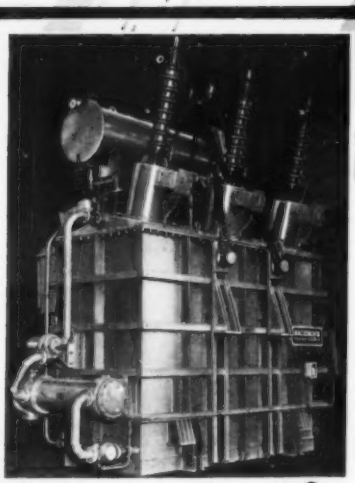

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Such a rate of tunnel driving is believed to
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Throughout the wide range of contracts upon
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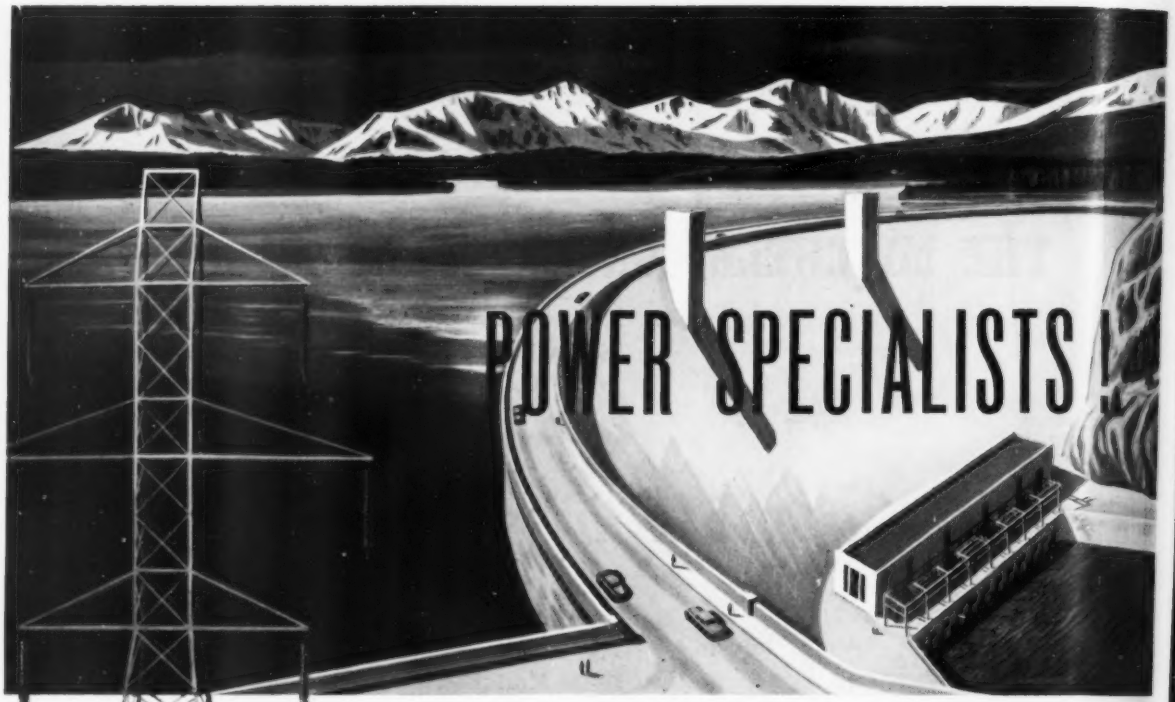

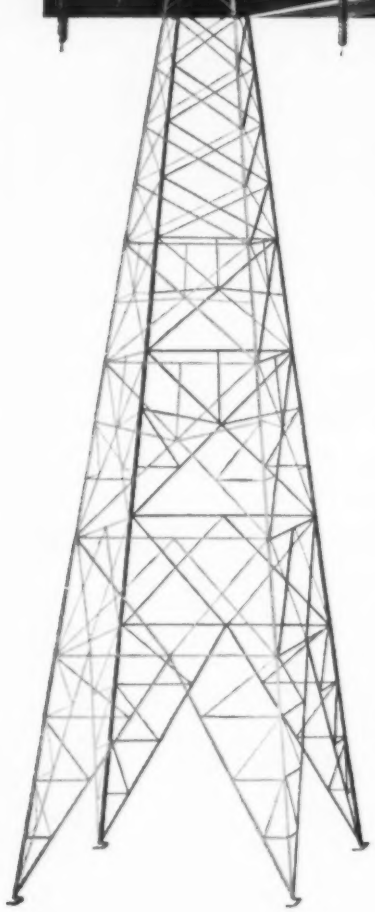

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ATLAS COPCO EQUIPMENT IN ACTION ON INDIA'S MIGHTY BHAKRA-NANGAL PROJECT

A power house under construction on the Bhakra-Nangal project. A wide range of Atlas Copco equipment and Sandvik Coromant steels have been used on many excavating and tunnelling operations on the project.

The turbulent River Sutlej is being harnessed under India's £113,000,000 Bhakra-Nangal project. It has three major aims. To prevent flood disasters, to irrigate six million acres of land, and to provide enough electricity for over 100 towns.

The Bhakra-Nangal project naturally means an immense construction programme. It includes the huge, 680-foot-high Bhakra Dam on the Sutlej. This is one of the highest ever planned in the world and the most important feature of the project. The dam will form a reservoir behind it with a capacity of 7.4 million acre feet of water, and the power houses at Bhakra will have an installed generating capacity of 1 million kilowatts.

57 Million cu. yards of rock

Atlas Copco rock drills, Sandvik Coromant steels and a wide range of other Atlas Copco compressed air equipment have been extensively used in excavation operations to construct the Bhakra Dam. These include excavations for the site of the dam, 575 feet wide at the base, for two cavernous diversion tunnels, each about 2,500 feet long, with the impressive diameter of 50 feet, and for four penstock tunnels. All told, this entailed the excavation of 57 million cubic yards of rock.

On other excavating operations for the Bhakra-Nangal project, Atlas Copco drills and Sandvik Coromant drill steels have again been chosen, along with Atlas Copco compressors, sump pumps, rock breakers, drill steel grinders and riveting tools.

Among equipment excavating for the foundations of the 680-foot-high Bhakra Dam are Atlas Copco rock drills fitted with Sandvik Coromant tungsten-carbide-tipped steels.

Atlas Copco drills and Sandvik Coromant steels are in action all over the world

Atlas Copco compressed air equipment is being used again and again on many more important projects throughout India. Since Atlas Copco light rock drills and Sandvik Coromant steels were introduced there five years ago, this equipment has been chosen for practically all Indian tunnelling projects of any size.

Here is an unbeatable *lightweight* drilling unit that has extensively replaced the heavy bar-rigged drifter. Atlas Copco rock drills and Sandvik Coromant tungsten-carbide-tipped steels have brought *faster drilling times, smoother progress at lower cost* on projects from Australia to Canada, Norway to Brazil. This drilling equipment was the obvious choice for India's mighty Bhakra-Nangal project.

Entrance to one of the two 2,500-foot-long diversion tunnels, each with a diameter of 50 feet, started with other equipment and finished with Atlas Copco drills and Sandvik Coromant steels.

The Prime Minister of India visits the Bhakra-Nangal project. Costing £113,000,000, it is one of the biggest power and irrigation schemes ever planned.

The services of the Project Department of Atlas Copco, whose job is to draw up drilling patterns and to advise on tunnelling and mining techniques, are at the disposal of mining engineers and contractors everywhere without obligation.

The Atlas Copco Group puts compressed air to work for the world. It is the largest group of companies specialising solely in the development and manufacture of compressed air equipment. It embraces Atlas Copco companies or agents manufacturing or selling and servicing Atlas Copco equipment in ninety countries throughout the world.

For further information about the equipment featured please contact your nearest Atlas Copco Company or Agent. There are Atlas Copco companies in Wembley (England); Paris; Rotterdam; Milan; Brussels; Copenhagen; Oslo; Stockholm; Essen; Madrid; Istanbul; Nicosia (Cyprus); Casablanca; Benoni (Transvaal, S.A.); Ndola (N. Rhodesia) and Belmont (S. Rhodesia); Montreal; Paterson N.J. and San Carlos Cal. (U.S.A.); Torreon (Mexico); Auburn (N.S.W. Australia); Wellington; Rio de Janeiro; Santiago de Chile; Lima. If you have difficulty in contacting your local Atlas Copco organisation please write to Atlas Copco AB, Stockholm 1.

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G.E.C.

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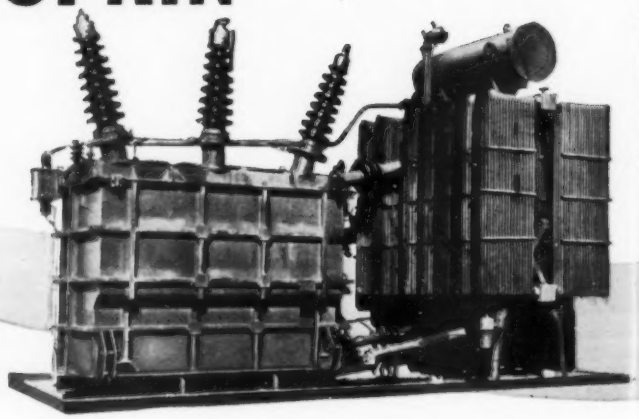

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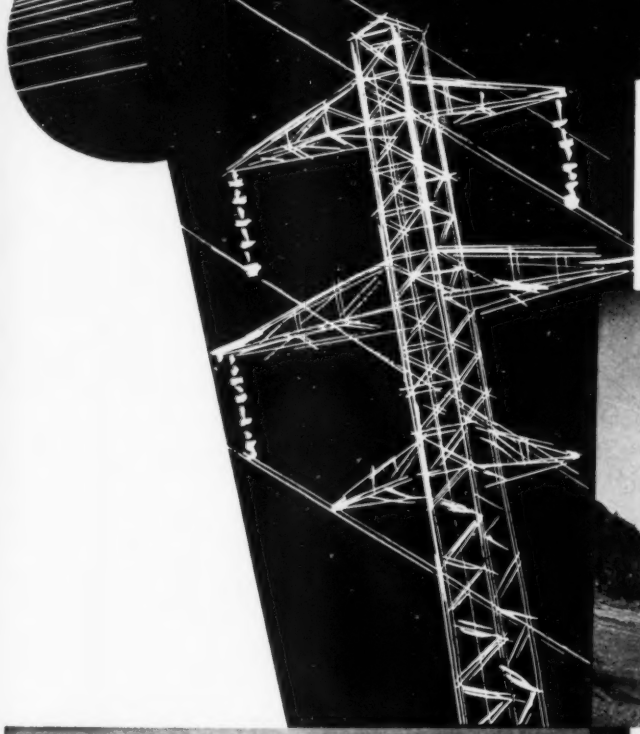

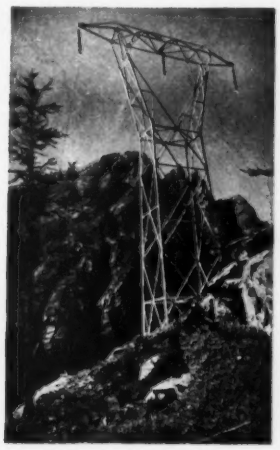

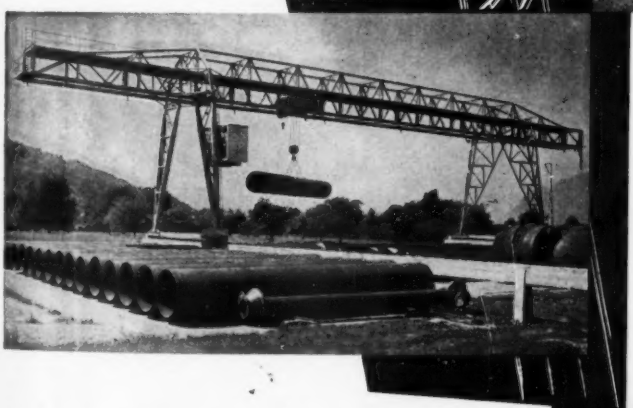

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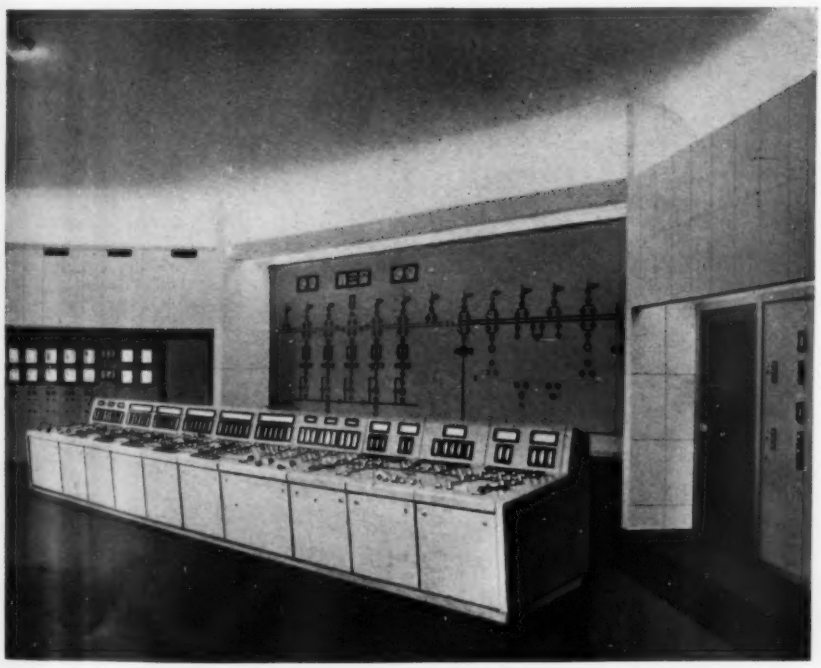
this is . . .

the railway junction of Attnang-Puchheim, Upper Austria, where tourists from all over the world are switched off the main line to lovely summer resorts

Photo: Österr. Bundesbahnen



. . . and that is

a part-view of a modern control room at Jochenstein Power Station on the Danube, where equally important switching operations are supervised and remotely controlled.

Photo: Elin

"ELIN" AKTIENGESELLSCHAFT FÜR ELEKTRISCHE INDUSTRIE

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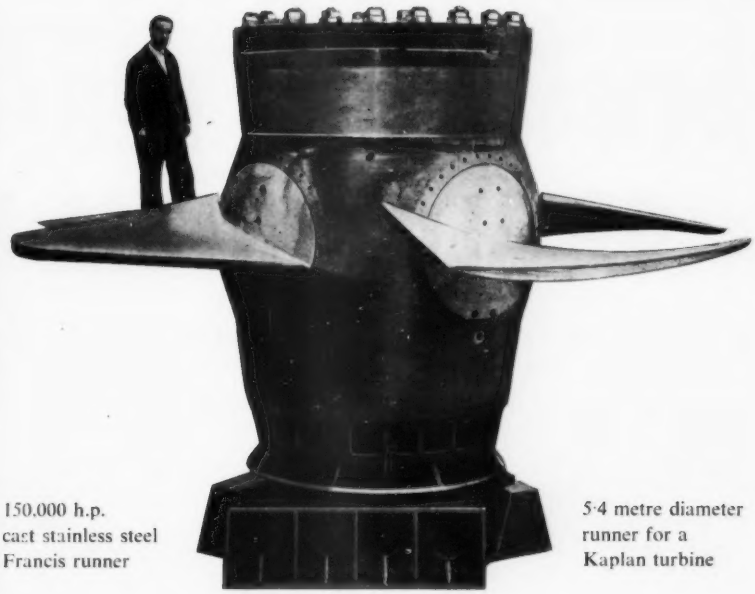
cast stainless steel
Francis runner



5·4 metre diameter
runner for a
Kaplan turbine

NOHAB

Leading Suppliers of Water Turbines

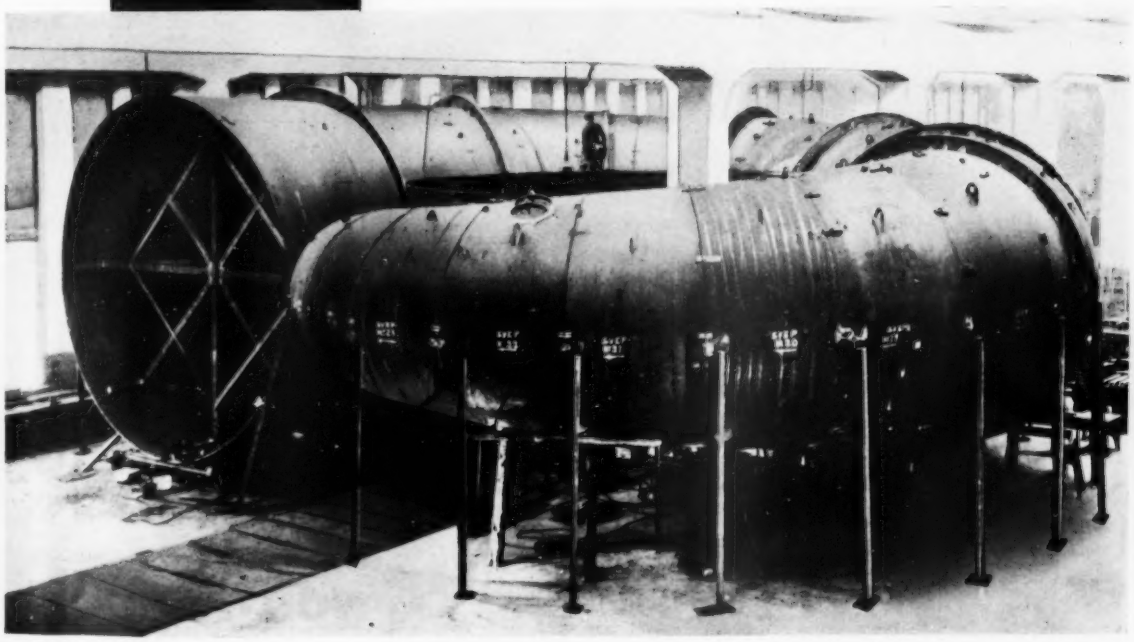


Plate steel
spiral casing, inlet
diameter 7 metre

Now under construction: Three Francis turbines—**the most powerful in the world**—max. guaranteed output 200,000 h.p. per turbine, for delivery to the power plant at Stornorrfors, Sweden

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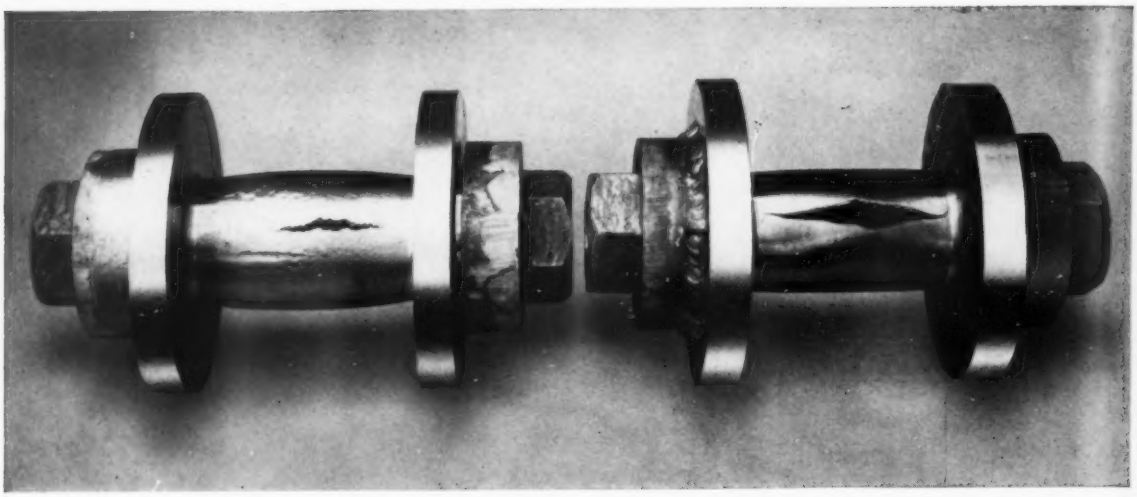
0·10 IN. SHELL WITHSTANDS OVER 2 TONS PER SQ. IN. !



Recently we tested to destruction two similar hollow castings—one in gun-metal, the other in aluminium-bronze. The gun-metal had a wall thickness of **0·25 in.** and withstood pressures up to 4480 lbs. p.s.i.—a very good performance. The casting in aluminium-bronze burst at a slightly higher pressure (4816 lbs. p.s.i.) **but its wall thickness was only 0·10 in.** Surely an impressive demonstration of the weight/strength characteristics of this alloy.

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LEFT *Gun-metal* **0·25 in.** *thick—burst at 4480 lbs. per sq. in.*

RIGHT *Aluminium-bronze* **0·10 in.** *thick—burst at 4816 lbs. per sq. in.*

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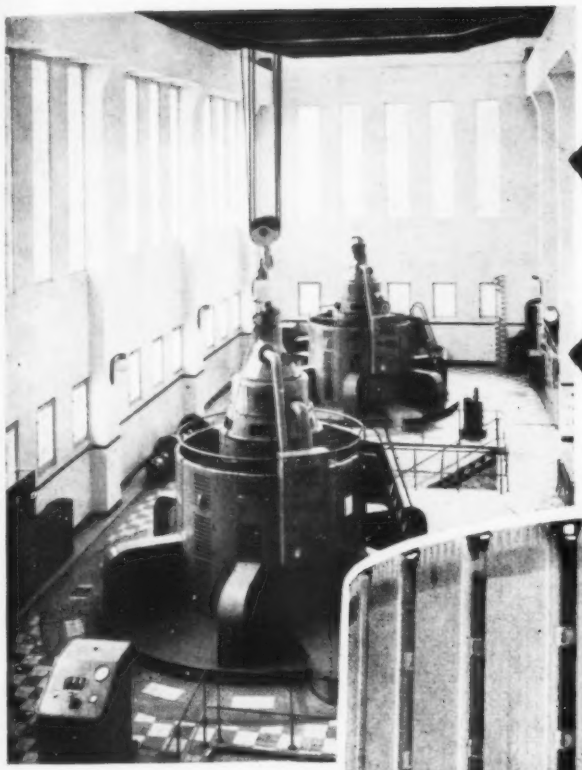

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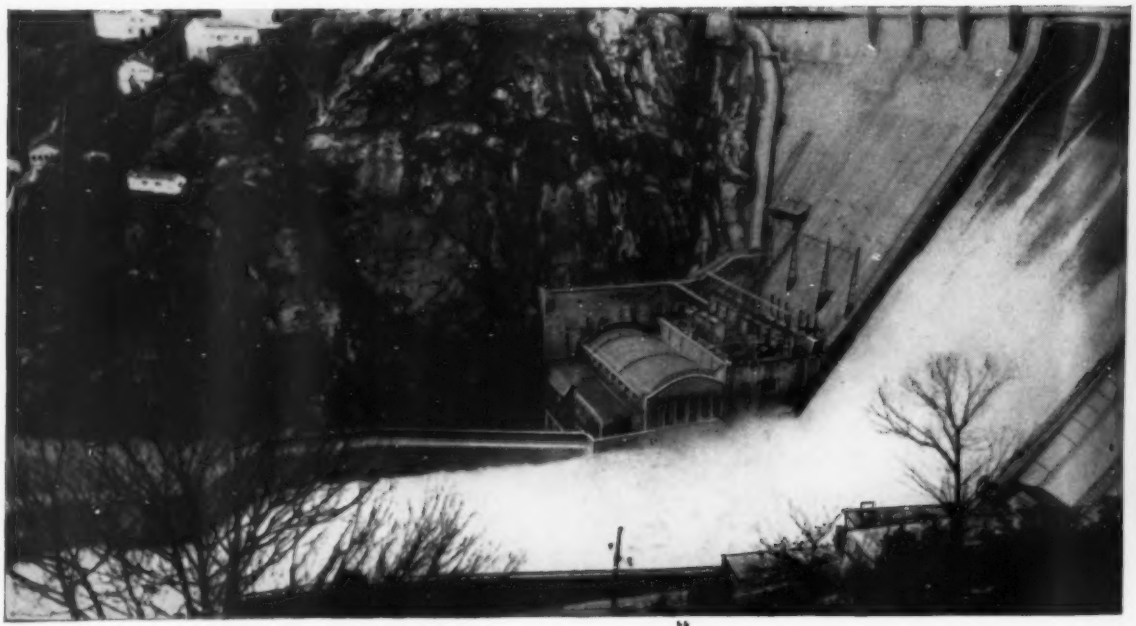
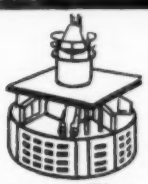
Los Peares Hydro-Electric Power Station

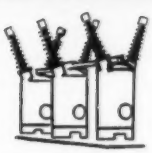
ANOTHER B T-H INSTALLATION



All over the world BTH hydro-electric equipment is helping to harness natural resources—helping to produce power and prosperity. In Spain, BTH (as main contractors) equipped completely the Los Peares hydro-electric power station.

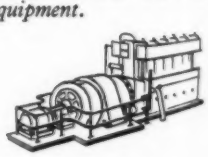


Generators. Three 62,400 kVA sets with Boving Francis-type turbines.



Main and auxiliary switchgear; control and relay equipment.

Generator transformers (ten, 20,500 kVA single-phase units), and distribution transformers.



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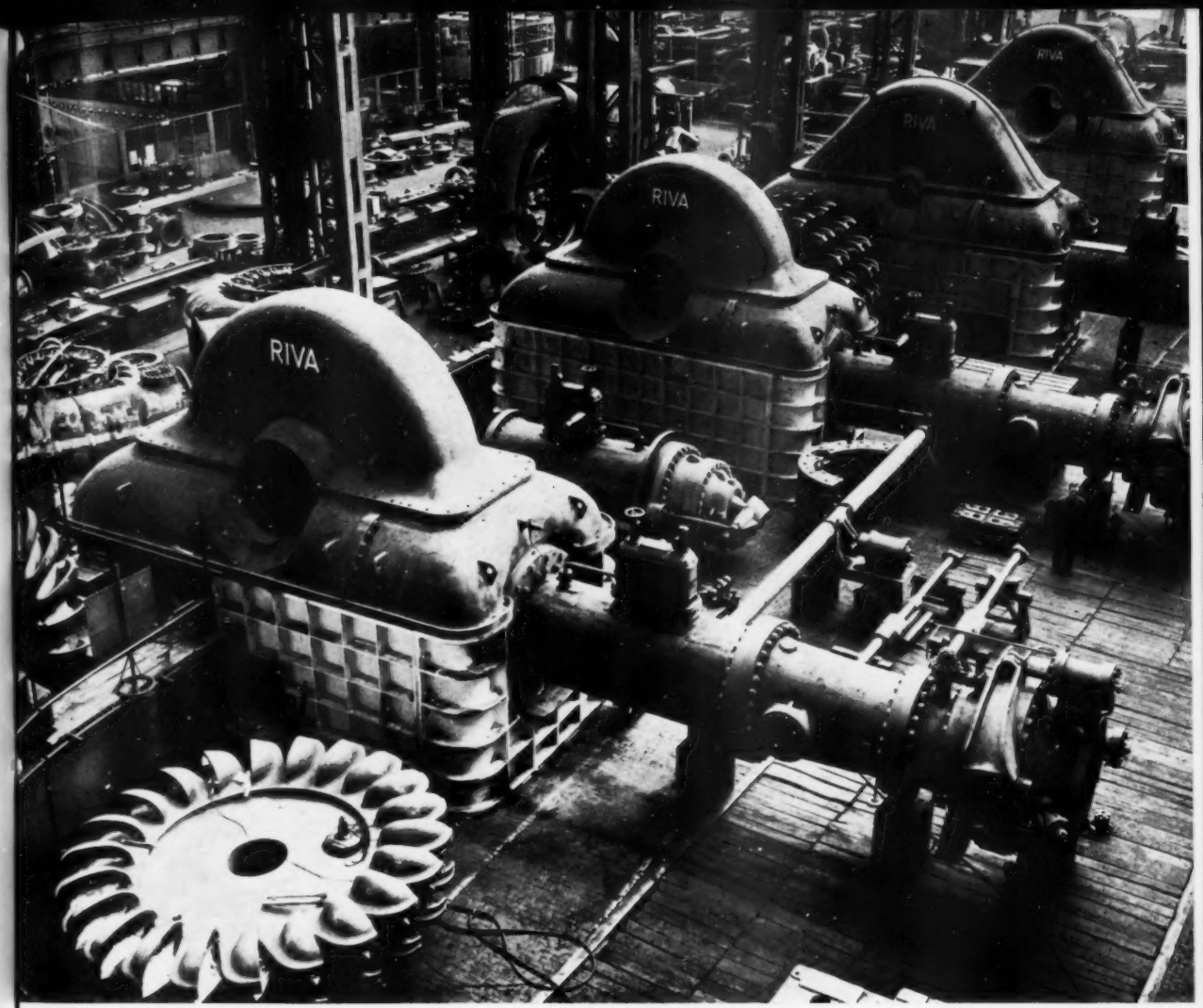

Main units actually in course of construction in our works :

PELTON : 2 Turbines each of 150,000 h.p. for Cimego Power Station, Italy.
2 Turbines each of 110,000 h.p. for Premadio Power Station, Italy.
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3 Turbines each of 45,000 h.p. for Hospitalet Power Station, France.

FRANCIS: 2 Turbines each of 80,000 h.p. for Somplago Power Station, Italy.
1 Turbine of 24,000 h.p. for Merdj-ez-Erraguène Power Station, Algeria.

KAPLAN : 1 Turbine of 35,000 h.p. for La Penna Power Station, Italy.
3 Turbines each of 15,000 h.p. for El Oviachic and Mocuzari Power Stations, Mexico.

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1735

719,000 kVA of FERRANTI Transformers for the Alcan Project

NEW CONTRACT

Ferranti Ltd. have been awarded a further order by the Aluminum Company of Canada Ltd., for 3-71,000 kVA, single phase Generator Transformers stepping up to 301,400 volts

These units will form the second 213,000 kVA bank of generator transformers to be supplied by Ferranti Ltd., for installation in the now famous "Power Station inside a mountain" of the Alcan Project at Kemano, British Columbia. The transformers will have aluminium windings, and it is believed that they will form the largest bank of transformers with aluminium windings in the world. This order brings the total number of transformers supplied or under construction by Ferranti Ltd. for the Alcan Project to 13 units of a total capacity of 719,000 kVA, to the value of 1,210,000 dollars.

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FT177/2

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ROTARY COMPRESSORS

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General View of the site of the Nile Power Station ASWAN.

We have been entrusted by the Egyptian Government, Ministry of Public Works, Hydro-Electric Power Commission, with the supply of the following equipment and materials:

TURBINE INTAKE GATES for

Main and Auxiliary Turbines including the Embedded Parts (16 gates),

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Operating Mechanism and Pumping Units.

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1 "Goliath" Type Crane for handling Main Turbine Draft Tube Gates.

1 "Goliath" Type Crane for service on the Intake Dam with extending Jib, Grab Bucket and 120 ton fixed Hoist.

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1 Road Transport Trailer,

1 Transporter Bridge,

1 7·5 ton Electrically Operated Hoist Block.

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WIEN **GRAZ**

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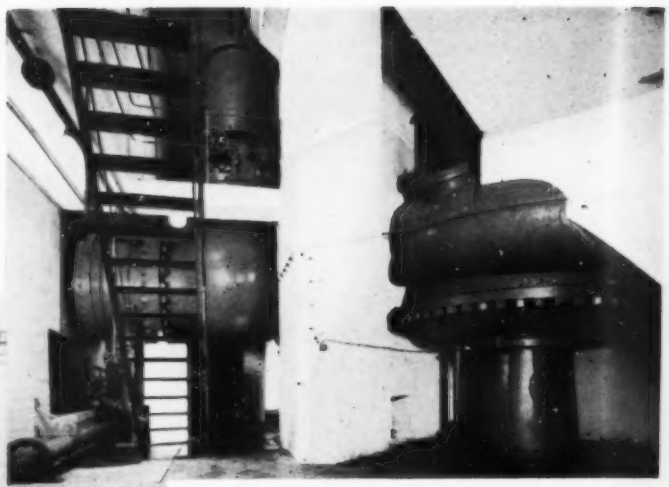
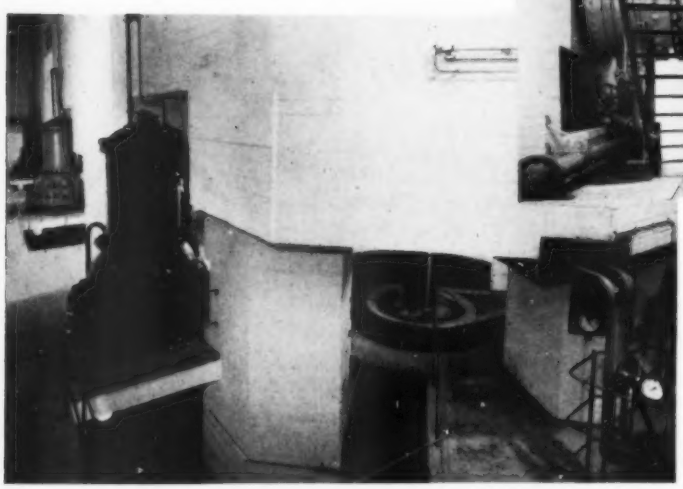
KVÆRNER Turbines

The turbines at Vinstra are the highest head Francis machines in Norway. They operate at 445 metres max. head and develop 70,000 h.p. each at 500 r.p.m.



View of one of the VINSTRA turbines and main sluice valve



Governor platform showing regulator ring of one of the turbines and parts of the main sluice valves.

In the near future we are passing 6,000,000 h.p. total output for turbine-runners delivered and on order.

Manufacturers of

WATER TURBINES OF ALL TYPES

GOVERNORS

HYDRAULIC SLUICES & VALVES

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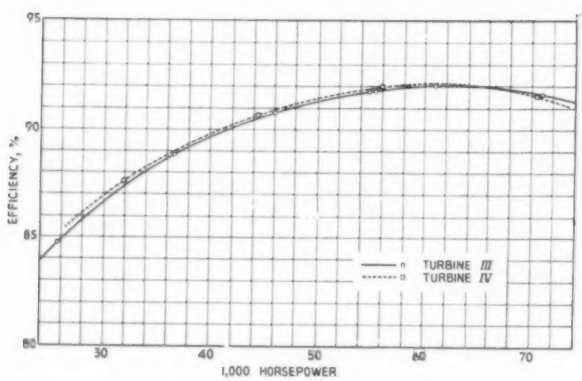

Efficiencies actually obtained on Vinstra turbines III and IV on official test, June 23-24, 1953

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Severely damaged by war and erosion, South Korea's Hwachon Dam has been a potential threat to the safety of people and property in the Han River Basin and the capital city of Seoul.

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The Merila Barrage is part of the Low Tana Hydro Electric Development in Kenya, which has been designed and constructed by Balfour Beatty for the East African Power and Lighting Co. Ltd.

The photograph of part of the barrage, which diverts water into the headrace tunnel, shows one of the 37′ 6″ span automatic control gates starting to open.

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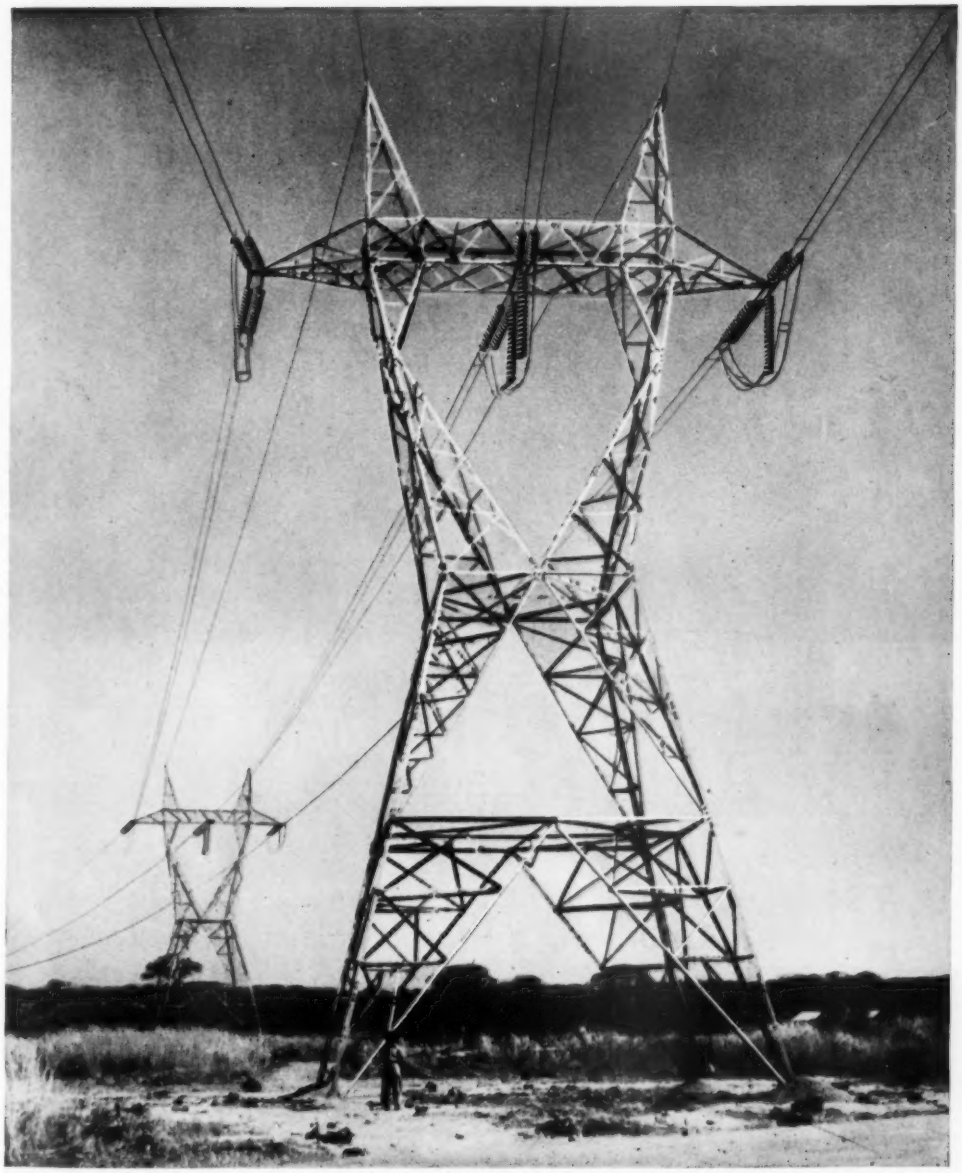

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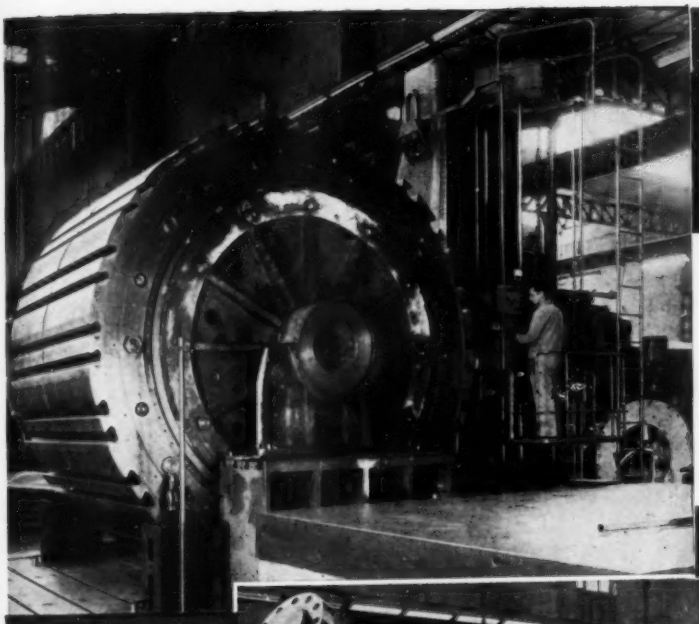

Marelli

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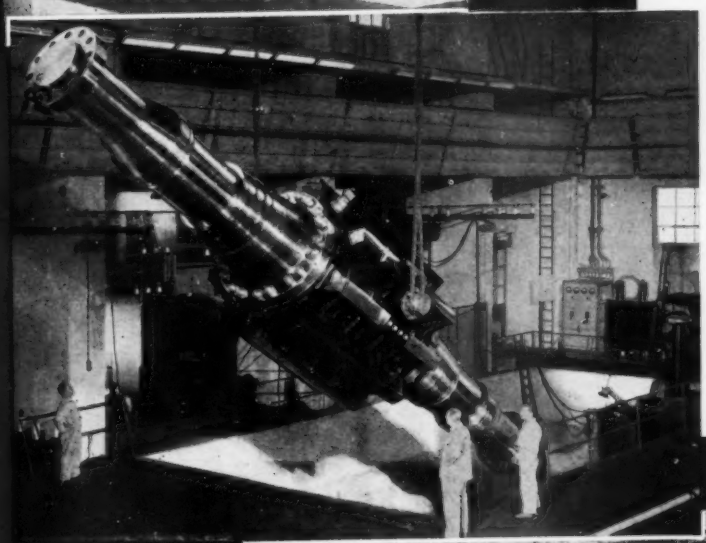
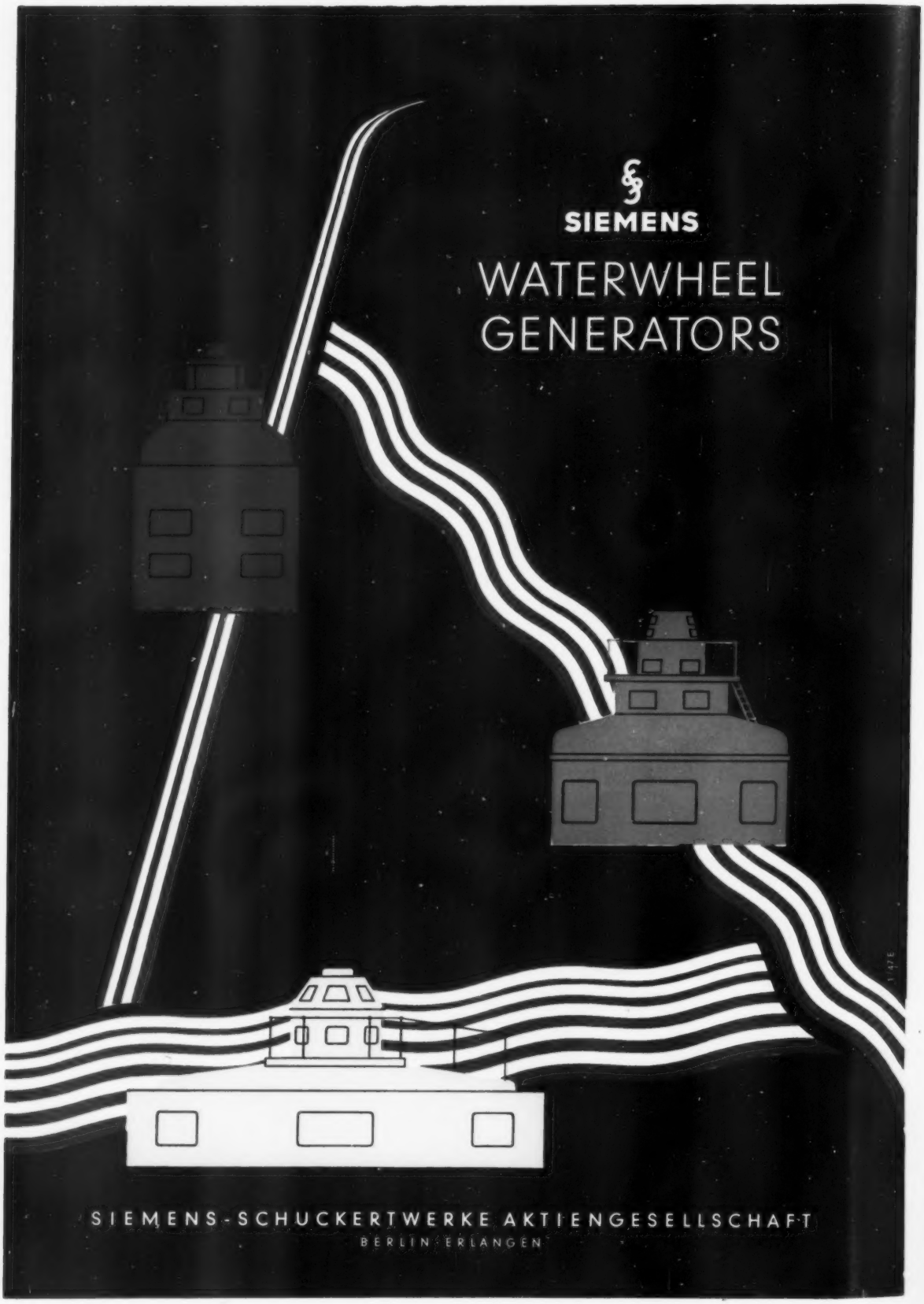


Rotor, shaft and stator for one of the two Water Wheel Alternators (110,000 kVA—13,800 Volts—300 r.p.m.—weight 650 tons) installed by Marelli in the Cimego Hydro-Electric Power Station of the Società Elettrica Bresciana (Italy). These alternators are believed to be the largest horizontal units yet built.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Volume 8 Number 8

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Editor: H. STOREY, M.C., B.Sc., M.I.M.E.

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the prospective new starts will appear to require a burial of sectional, intersectional, international, and political philosophy differences in the interests of the common good. To continue to engage in prolonged bickering so that essential projects are delayed until "brown-outs" occur and there follows a costly and frantic effort to regain the lost time may do irreparable damage to the economy of this great region. Rather, a common-sense course of action demands early amicable settlements of the controversial issues so that the people of the Northwest can go forward with the most practical and economical development of additional electric power resources as and when required."

We could not agree more.

A matter of great technical interest that is emerging from this situation is that of the possible correlation of hydro and thermal power, and an exhaustive study of this question is being made by the Washington State Power Commission. The planning-construction period for a steam station in this region is about three years as against five years as a minimum for a hydro-electric scheme, and a proportion of thermal power may help to beat the timetable. Nevertheless, the Washington Power Commission's study is not directed to the emergency use of steam in default of hydro, but to the fundamental issue of ascertaining whether an integrated hydro-thermal system can be planned to present the optimum economy for the Area. Low-load-factor steam stations are envisaged the function of which would be to firm up high-probability secondary hydro power, and it is thought that this additional firm power may be made available more economically than by providing equivalent additional water storage.

This question of the correlation of hydro and thermal power has been engaging the attention of engineers in many parts of the world, and we ourselves have commented on it on more than one occasion, but it is a comparatively new conception to many in the Pacific Northwest because hydro resources are so abundant that there has been little incentive to consider alternatives. That is all the more reason why the Washington State Power Commission are to be congratulated on their foresight in undertaking this investigation, and when they are in a position to publish their conclusions, those conclusions will be studied with universal interest.

New Zealand's Hydro Policy

THE New Zealand Government strongly favours water power in preference to nuclear development. This was emphasised by the General Manager of the State Hydro Electrical Department, Mr. A. E. Davenport, when he recently addressed a gathering of South Island local body representatives at Christchurch. Mr. Davenport emphasised that New Zealand natural resources were suited for hydro development, and indicated that the New Zealand Government would be probable purchasers of hundreds of millions of pounds worth of hydro-electric equipment in the years ahead.

Most of the new hydro-development will be in the South Island, where the power potential is between 5,000 and 6,000 MW, against 1,250 MW, plus, in the North Island. If Cook Strait did not exist, there would be no question in anybody's mind as to what they did. If technical development showed, and the practical experience of other people showed it definitely, that it was possible to link the two islands, there could be no question which way the answer would go. It was calculated that between 1962 and 1972, the North Island would require 24,000 million kWh above its production. If that had to be provided in the nuclear way, the capital and operating costs would be £50,000,000 more than if the Department went the hydro way with a cable. At the stage the North Island would arrive at in 1972, the annual excess by doing it the nuclear way was more than £10,000,000 a year. Those were the broad economics as known. The transmission of 300 MW across Cook Strait would require six alternating-current cables, plus a spare. The same power could be transmitted with half the loss on direct current on two cables, plus a spare. That was one of the major choices on which a decision was required to be made before very long.

Loan for Kariba

THE International Bank has agreed to make a loan of $80 million (about £28,600,000) to the Federal Power Board of the Federation of Rhodesia and Nyasaland towards the cost of the first stage of the Kariba scheme. The total cost of this stage, which will provide a generating capacity of 50 MW, is estimated at about £80 million, including the cost of nearly 1,000 miles of transmission lines. The remainder of the cost is to be met by loans of £15 million from the Colonial Development Corporation, £3 million from the Commonwealth Development Finance Co. Ltd., and up to £34 million from the Federal Government of Rhodesia and Nyasaland. Actually the Federal Government will only need to find about £5 million from its own resources, as it was announced in February that the Nchanga, Nkana, Mufulira and Roan Antelope copper companies would between them advance £20 million, the British South Africa Company £4 million, Barclay's Bank £2 million, and the Standard Bank of South Africa £2 million.

Tunnel Obstruction at Kitimat?

MEASUREMENTS of the flow of water in Kemano tunnel indicate the probability of an obstruction near its centre where the closing off of an access tunnel left an enlarged section. The possibility of a rock fall such as could cause a partial blockage is greater at this point than elsewhere in the tunnel. It will be necessary to unwater the tunnel to obtain a complete explanation of the interference with flow, and this will be undertaken in a manner planned to avoid interruption of aluminium production at Kitimat. In the opinion of the Company's engineers, subject to the findings when the tunnel is entered, some remedial work not considered to be of a major nature may be necessary to ensure that the full amount of power will be available for the planned expansion at Kitimat during 1957, 1958 and 1959.

The power now obtainable in spite of the observed loss of head is in excess of that required to supply the Company's existing smelters at Kitimat as well as the additional smelter unit now under construction, representing an aggregate annual capacity of 180,000 tons of aluminium to be in operation towards the end of 1956.

Scheduled expansion of the Kitimat smelter calls for an additional 150,000 tons of annual capacity, by 1960. The Company's smelters in the Province of

Quebec are now operating at their full capacity of 580,000 tons per annum and present plans call for further expansion of its Quebec smelters to bring total Quebec smelting capacity to 700,000 tons by 1960.

Kotla Power Station Inaugurated

KOTLA power station, which is the second to be commissioned on the Rs. 110 crore (revised) Bhakra-Nangal power project in East Punjab, was inaugurated on June 9 by India's Home Minister, Mr. G. B. Pant. The Ganguwal power station, the first to be commissioned, was inaugurated in January last year by President Dr. Rajendra Prasad. The Kotla station, work on which was commenced in January, 1952, is 6 miles from the Ganguwal station and 18 miles down the Nangal Hydel canal which has been excavated at a point about 8 miles below the Bhakra dam. This station and the appurtenant civil works cost Rs. 4·80 crores. It is unique in India in that, although it is a main generating station, it has been so designed that it can be operated by remote control from the Ganguwal station through supervisory and telemetering equipment. It is the first time that such operation is being tried in India. It has had two of its 24,000 kW units installed and fully loaded so that with its inauguration firm power available will be increased to 70,000 kW. The station has been designed to house a third 24,000 kW unit.

World's Longest Salmon Ladder

IN the Rana River, North Norway, the world's longest salmon ladder is nearing completion. Main feature of the ladder is a tunnel about 500 yards long blasted out of rock. Up to now the salmon has only ascended about five miles up the river. The tunnel will enable the salmon to travel many miles further up-stream, and greatly increase the stock of fish in the river. Total cost of the scheme is £18,000, which the sponsors believe will be covered by the income from the increased salmon yield next year.

Hydro Project for Tourists

THE New Zealand Government is to install a small hydro-electric plant at Quinton Huts, on the Milford Track. Quinton Huts provide accommodation for 48 guests. The cost of the completed hydro-electric scheme, including machinery, installation and transport, is estimated at £7,000. It is hoped to use a helicopter to place the materials on the site, and to finish construction before the end of next season. The improved power facilities will mean a better standard of service for parties travelling over Milford track (described as the "world's loveliest walk"), which is becoming more popular following the reopening of the Milford Hotel. We understand that a 60 kW set operating under a head of 270 ft. is envisaged.

Clowhom to be Rebuilt

A $4,000,000 project to rebuild the Clowhom generating station and expand its capacity ten times to 40,000 h.p. has been announced by B.C. Electric. The completed station, which will be fully automatic, is scheduled to start operating in September 1957. Clowhom was built some years ago by the B.C. Power Commission and is located at the end of Salmon Inlet, north-east of Sechelt, 40 air miles from Vancouver. The present capacity of the plant is entirely absorbed by homes and stores in the Sechelt area, which receive power over a 60 kV circuit.

More water will be needed to run the larger generating unit. To impound it, the present dam will be raised to 80 ft. and extended in width to 1,600 ft. A steel penstock, 14 ft. in diameter, will drop the water 185 ft. to the generating unit.

The contract for the turbine has been awarded to Vancouver Iron Works, which has made six of the eight machines for B.C. Electric hydro-electric projects placed in operation since the end of the war. Canadian Westinghouse will make the generator.

The Miguel Hidalgo Dam

THIS year the Miguel Hidalgo dam in Sinaloa, Mexico, will irrigate 230 thousand hectares of high-quality land, and when it is finished this figure will rise to 300,000 hectares. The project is advancing satisfactorily and excellent economic and speed records are being achieved in its construction. This dam will store 3,000 million cu. m. of water, and will be a decisive factor in the taking in of harvest worth $575 million pesos in each agricultural cycle.

During the initial period the water will be devoted to crops, generation of electricity, and ending floods caused by the Rio Fuerte. Of the total storage available, 2,700 million cu. m. will be used for irrigating crops and generating electricity and the remaining 300 million for silt deposit.

The dam will be 3 km. long, 10 m. wide at the crest and 270 m. wide at the base. The maximum height from the river bed will be 68 m., and 74 m. from the foundation excavation. 7·3 million cu. m. of material have been used in the construction of the dam which is the largest project undertaken by the Federal Government in the state of Sinaloa.

The Recent Conferences

IN this issue we conclude our summary of the papers given at the CIGRE Conference. In forthcoming issues it is our intention to publish surveys of the Conference on Power from the Sea and of the World Power Conference.

Mr. J. S. Hunter Retires

Mr. J. Stanley Hunter, Executive Director (Advertisements) of Tothill Press Limited retired on June 30 after 44 years' service with the company and its predecessors. Mr. Stanley Newman continues in his position as Executive Director (Advertisements) and Mr. Gordon Brunton has been appointed Advertisement Director. On June 28, Mr. George Rollason, Deputy Chairman, Tothill Press Limited, made a presentation to Mr. Hunter on behalf of the staff at St. Ermin's Hotel, S.W.1.

Ybbs Persenbeug. In connection with the article on this Austrian station which we published in our June issue we regret the name of one of the consultants was misspelt. The name of the general and landscape architect was Herr H. Scheide, and not Herr H. Schneider as printed.

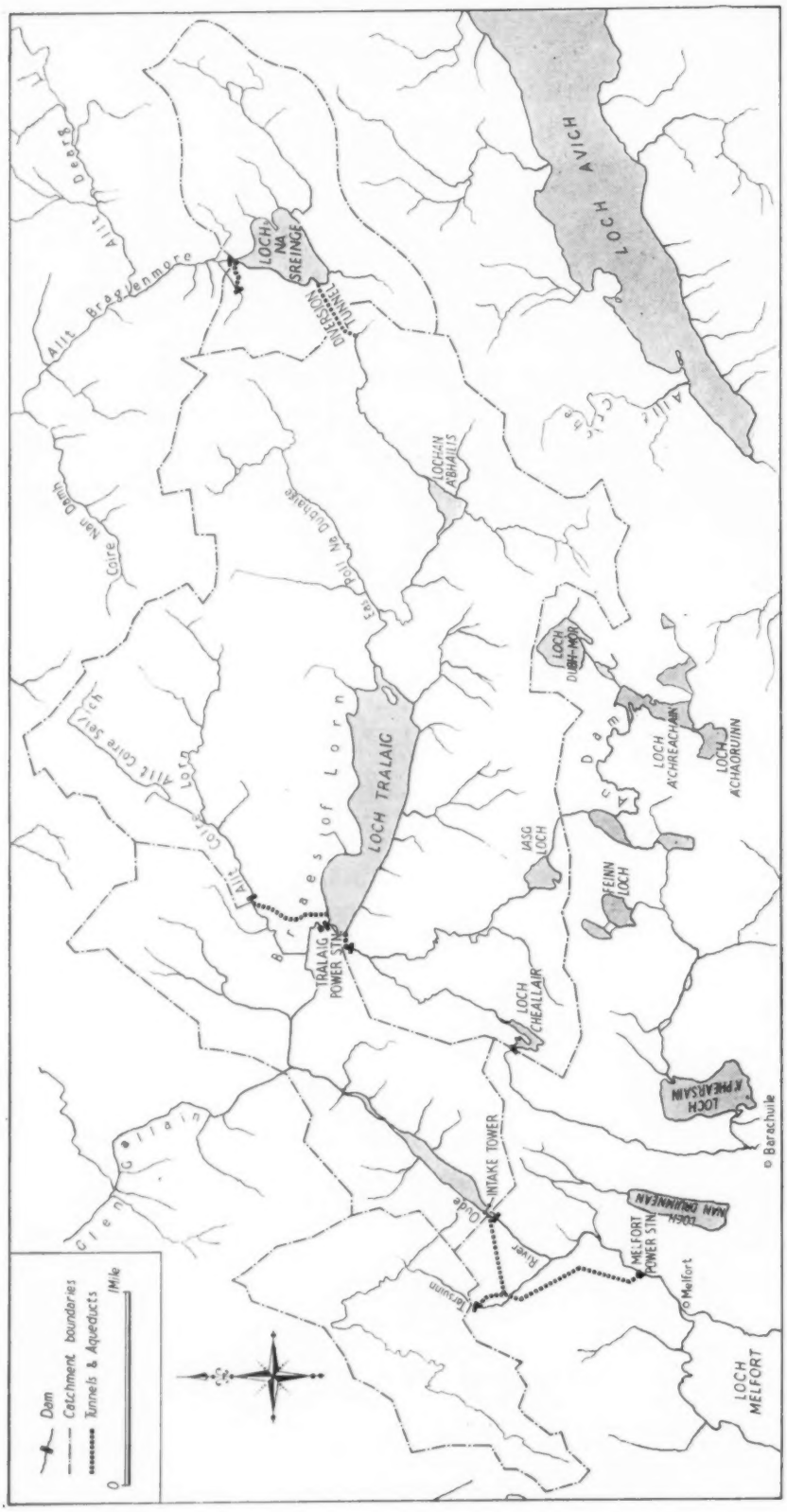


Fig. 1. Map of the catchment area of the Kilmelfort development, showing the disposition of the dams, tunnels and aqueducts, and power stations

KILMELFORT

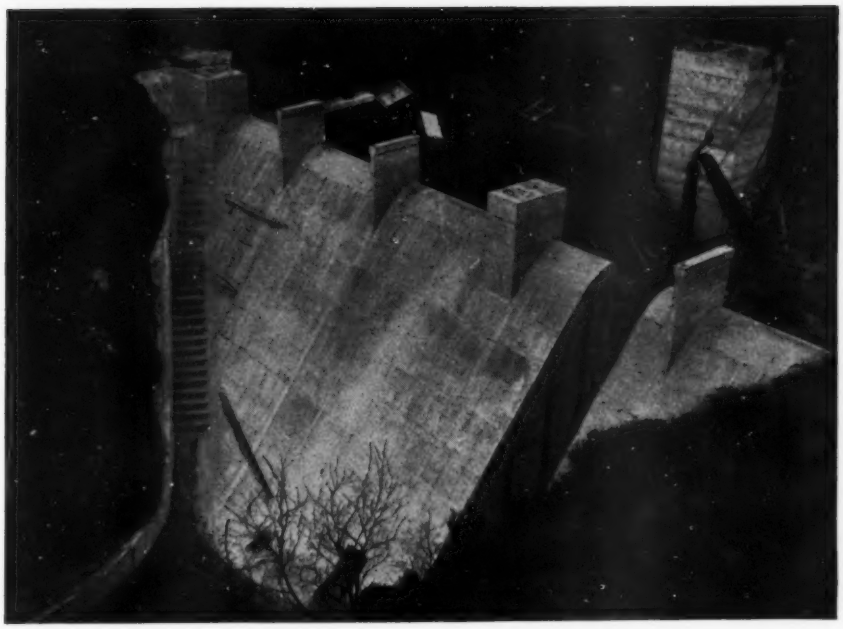


Fig. 2. Oude dam from the south bank

Kilmelfort

This article describes one of the smaller schemes which the North of Scotland Hydro-Electric Board have initiated to pick up a parcel of power from the River Oude and other adjacent streams, in the County of Argyll

THE Kilmelfort scheme utilises the water from a catchment area of 11·1 sq. miles on which the rainfall averages some 77 in. per annum. The main catchment, which drains an area of 8·7 sq. miles, has Loch Tralaig as its centre and is fed by the headwaters of the River Oude. Farther to the east this catchment is augmented by the headwaters of the Allt Braglenmore, with a cachment area of 1·23 sq. miles, which drain into Loch-na-Sreinge and are there impounded by a dam at the northern exit and subsequently diverted west to the Oude catchment by a gravity aqueduct in a tunnel 1,800 ft. in length. Downstream of the Tralaig dam two tributaries of the Oude are diverted back into the lock by pipe aqueducts, of 36 in. and 27 in. diameter and 760 yards and 100 yards in length respectively. These are of spun concrete, painted inside and out with bitumen. There is a final extension of the catchment to the west where 1·1 sq. miles of the catchment of the Eas Tarsuinn was diverted through a 36 in. diameter pipe aqueduct 725 ft. in length. This water is not diverted to the main impounding reservoir (Loch Tralaig) but is discharged directly into the pressure tunnel leading to the power station or alternatively in times of shutdown back into the headpond.

The natural level of Loch Tralaig is in process of being raised 30 ft. by a mass concrete spillway dam which is flanked on either side by earth and rockfill embankments. The concrete dam is 35 ft. in height above the river bed and 190 ft. in length. The embankment on the north side is 205 ft. long while the southerly limb is 550 ft. long with a maximum height of 15 ft. in the centre. Both embankments have a concrete core wall, carried down to bedrock, and this is flanked by zones of fine material (sandy, gravelly soil) with an outer protective coating of rockfill and the reservoir side further protected by stone pitching. The quantity of water impounded by these means amounts to 235 million cu. ft., equivalent, at the total head available, to about 1·5 million kWh. In the concrete portion, a small power house is incorporated and will be equipped with a vertical-shaft propeller turbine of 83 kW capacity. This machine, which works on an average head of 21 ft. and was supplied by Gilbert Gilkes & Gordon Limited, regulates the flow from the storage reservoir to the headpond of the main generating station, some 1¼ miles downstream. The turbine is coupled to a 415 V asynchronous generator of Bruce Peebles manufacture and is arranged for hand regulation to give a fixed discharge of 50 cusecs

over its range of operation. An overspeed trip will be fitted to close down the turbine should an overspeed occur. A 4 ft. square scour sluice in the base of the dam provides for the bypassing of the turbine when necessary.

The discharge released from the storage reservoir is afforded free flow along the bed of the Oude until it reaches the headpond to which reference has already been made. As might be expected, this 1½ mile stretch of the river is flatly graded, the difference between storage-reservoir tailwater and headpond top water being only 28 ft., so that very little useful head is lost. The dam forming the headpond is situated at the head of the Pass of Melfort and has a useful capacity of 23 million cu. ft. This storage is created by a mass-concrete spillway dam having a height of 45 ft. above the river bed, and a length of 150 ft.

It has already been mentioned that the flow from the Eas Tarsuinn stream, to the west of the main catchment, is diverted into this headpond, and actually, at times of no load, this is so, but when the main generating set is operating, this water is delivered directly into the pressure tunnel.

The penstock between the headpond and the power house consists of a low-pressure section consisting variously of a tunnel having a length of 2,462 ft., and an equivalent lined diameter of 6 ft. 3 in.; a 225 ft. length of steel pipe, 54 in. in diameter, to conduct the flow across the Eas Tarsuinn; and a further 2,600 ft. length of tunnel which, like the first, is of horse-shoe section and is 6 ft. 3 in. equivalent lined diameter. From this last tunnel a high-pressure steel pipeline, 45 in. diameter and 400 yards in length, leads down to the power house. This is a pleasantly architectured structure, built of Bonawe granite, and is situated at the foot of a deep gorge which has been hollowed out by the Oude and its antecedent glaciers. It is situated about half a mile upstream of the point where the Oude enters Loch Melfort, which opens directly to the sea.

Both the tunnels and the foundations for the headpond dam were excavated in andesite lavas. In the tunnels the rock encountered, all of the lava class, was generally firm and dry. It had been hoped to leave a considerable proportion of the tunnels unlined but as over most of the length the rock was either unsound or subject to deterioration from the action of water it was decided to line them with unreinforced concrete. At the same time an experiment was made with gunite lining over a length of 270 ft.

Two types of gunite lining were adopted, the first consisting of a 1½ in. thickness without reinforcement where the rock was sound but liable to weather, and the second 3 in. thickness reinforced with a 4 in. mesh of high-tensile 9 gauge wire where the rock was not so sound and subject to breaking up, at the exposed surface, into small pieces due to calcite infiltrations. No attempt was made to secure a uniform section and all irregularities of the rock were followed with the gunite. Tests on the bonding proved satisfactory, amounting indeed to 40-50 lb. per sq. in. after seven days on the type of rock to which 1½ in. thickness of gunite was applied. The early assessment of this form of lining promises some advantages over

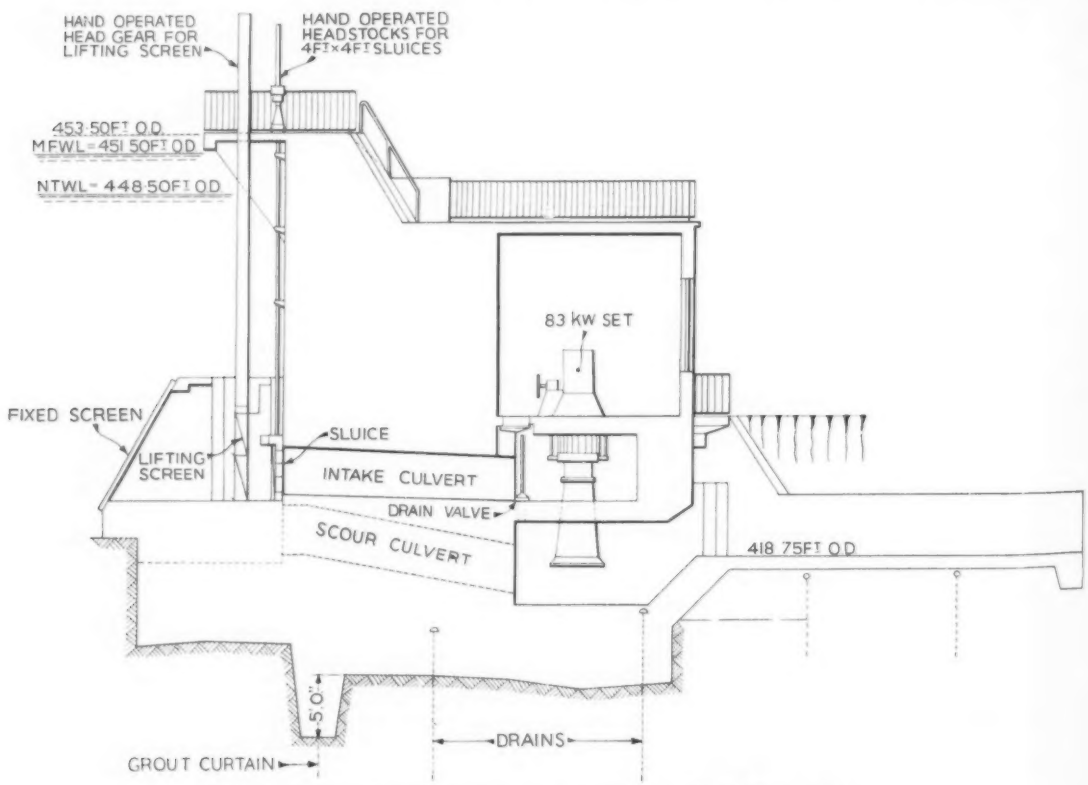


Fig. 3. Section through power-station portion of Loch Tralaig dam

Fig. 4. Pipeline for Melfort power station in course of erection

normal-type lining where the strength of the rock is not in doubt, since there are distinct savings in materials together with a resultant increase in cross-sectional area of the finished tunnel and a small reduction in frictional losses. The cost of this work on the test section compared favourably with that of normal lining.

Tunnel excavation was commenced initially at the Eas Tarsuinn stream on two headings and since the hydraulic characteristics of the tunnel cross-section were not critical the contractor elected to drive to the minimum permissible size, 5 ft. × 5 ft. 6 in., using standard drilling equipment—Atlas Copco drills on light airlegs with tungsten-carbide tipped drill steels—and employing hand mucking into monorail skips. This method proved reasonably satisfactory for distances up to about 800 ft. and the rate of advance was about 10 yards per week of single-shift working. Experience proved that this was the limit of this method, both from the point of view of time to muck out and also because the restricted working room precluded the installation of a sufficiently large air duct to provide the degree of ventilation essential for the petrol-driven monorail unit.

A change to orthodox equipment was then made and driving commenced on a 7 ft. × 7 ft. 6 in. heading from the downstream end of the second tunnel using an Atlas Copco L.M. 30 loader and standard 2 ft. gauge track, diesel locos and $\frac{5}{8}$ cu. yard skips. Drilling as previously was carried out by two machines on the face working on a 5 ft. length of hole. With this latter method an average advance of 582 ft. per month was maintained, working two 12 hour shifts 5½ days per week, the maximum advance being 201 ft. in one week of 12 shifts.

Concrete lining for the tunnels was carried out using a concreting train consisting of $\frac{3}{8}$ cu. yard pneumatic placer with air receiver, electrically driven conveyor, turntable and ramp, and the concrete was placed behind timber panel shutters supported on steel arch ribs set on previously concreted haunches, the sequence of operations being haunches, roof and sides, invert and lastly cavity grouting and pressure grouting where necessary followed by protection of the lining with bituminous paint.

Concrete was fed to the concreting train initially from the central mixer at the headpond dam and latterly from another mixing point at Eas Tarsuinn supplying two headings at one time. Transport of the concrete through the half-mile length of each tunnel was by diesel loco and the $\frac{5}{8}$ cu. yard muck skips, and no adverse effect from segregation of the concrete materials was noted, although strict control of the water/cement ratio was required to obviate this. All concrete was weigh-batched. The diesel locos were eventually replaced by electric locos. Tunnel lining for the most part was carried out continuously from Sunday night until Saturday morning each week at an average rate of 390 ft. per week—the maximum being 500 ft. in one week.

The excavations for the headpond dam were in andesite lava, similar to that in the tunnels, and apart from a fault in the line of the river which necessitated the foundations being carried down farther than anticipated, gave rise to no special difficulties. Pressure grouting of the foundation rock indicated that it was exceptionally tight and even in the fault zone very few holes accepted any cement.

In the case of the Loch Tralaig dam and embankments, however, the excavations disclosed that the

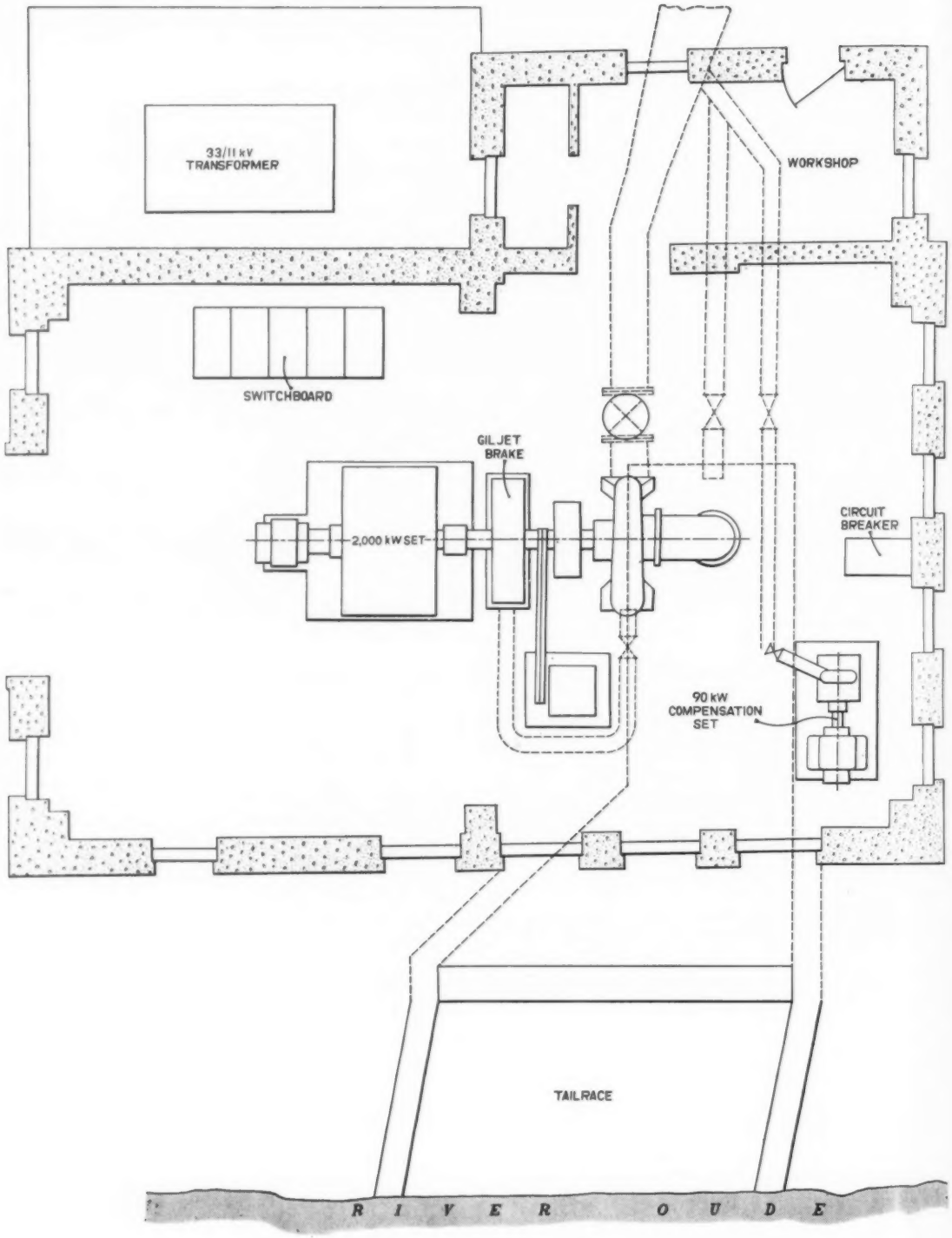


Fig. 5. Plan of Melfort power station showing the disposition of the 2,000 kW horizontal Francis set with Giljet braking and the 90 kW induction-generator compensation set

epidiorite rock there, which was expected to prove sound, was in fact weathered and fissured to a considerable depth, calling for extra excavation and finally a comprehensive pressure grouting programme to ensure against leakage. Foundation drains were also provided in this dam for the relief of uplift pressure. Excavations for this dam were further complicated by two broad and two narrow dolerite dykes together with a fault in the line of the river, all of which gave rise to much soft and broken rock which had to be excavated.

A feature of the concrete dam at Loch Tralaig is that the spillway face is formed with precast massive concrete blocks, which added considerably to the speed with which each successive lift of the dam could be poured.

The embankment fill was consolidated, both hydraulically and by mechanical vibrators in the case of rockfill, and by vibrator only in the case of the fine material.

The conditions in the Loch-na-Sreinge diversion tunnel were similar to those obtaining in the other two tunnels and tunnel driving was carried out from one heading from the Loch-na-Sreinge end—the cross-section being 7 ft. × 7 ft. 6 in. horseshoe. In view of the fact that this is a free-flowing aqueduct only those sections where the rock is soft and unsound will be lined.

All concrete aggregates for the work were imported—coarse aggregate being crushed granite from both Bonawe on Loch Etive and Crarae on Loch Fyne, distances of up to 40 miles. A good source of rock for aggregate was available on the site, but it was considered uneconomic to open this up for the quantities required. Pit sand was obtained from North Connel on Loch Etive. The local granite—a pink porphyry—was latterly quarried and used both for embankment pitching and also rockfill at Loch Tralaig.

The pipeline, 45 in. in diameter at the top and tapered down to 24 in. at the point of attachment to the turbine valve, is in five sections between anchor blocks, each section being provided with a sleeve-type expansion joint. The pipes have long sleeve-welded joints with two welds per joint, one internal and the other external. Above each block there is a Dutchmen-type joint consisting of two non-paralled faced rings fitting between flanges which permitted any lateral or vertical error in alignment during erection or concreting to be accommodated. The flange also facilitated sealing each section during tests. The pipes are supported on pedestals and rest on two graphite-impregnated plastic pads, Ferrobestos, to reduce friction. The portal valve at the top of the high-pressure pipeline has the distinction of being 28 years old, having originally been installed at Luichart. It is of the hand-operated butterfly type and was manufactured by Boving & Co. Ltd., who, as the present condition of the valve testifies, obviously believe in making things to last. The pipeline is also provided with an anti-vacuum and air release valve at its upper end.

The generating equipment in the Melfort station is to consist of one main set, comprising a horizontal-shaft Francis turbine coupled to a 2,000 kW generator, and a 90 kW Turgo-driven set designed to pass the specified amount of compensation water to the Oude at all times. Both turbines operate on an effective head

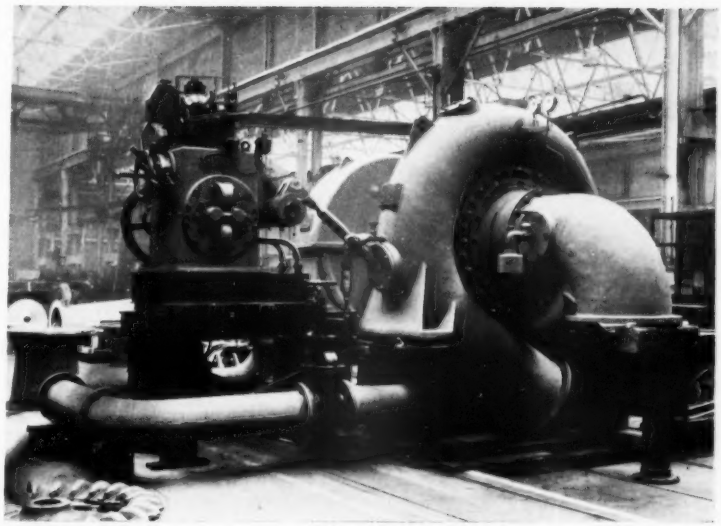


Fig. 6. The 2,000 kW turbine in the works of Gilbert Gilkes & Gordon Limited

Fig. 7. Oude bridge and roadway

of 340 ft. (365 gross) and were supplied by Gilbert Gilkes & Gordon Limited of Kendal. The larger has a normal speed of 750 r.p.m. and is directly coupled to an 11 kV synchronous generator, manufactured by Bruce Peebles & Co. Ltd. It is fitted with an oil-pressure governor and in addition, a Giljet governing equipment is being provided to limit the speed rise and to prevent the creation of other than moderate pressure surges when load is suddenly thrown off. With this device, excessive pressure build-up when load is rejected is prevented by directing a supplementary jet against an impulse-type brake runner, which is fitted with specially shaped buckets on which the jet impinges. The resulting deceleration assists the work of the governor, thus assuring close speed regulation, while the pressure increase in the pipeline is appreciably reduced by the temporary release of water through the escape jet. This set is shown in course of erection at the maker's works in Fig. 6.

The turbine is isolated by means of a 24 in. bore Glenfield & Kennedy hydraulically operated sluice valve, fitted with a d.c. solenoid trip for closing the valve.

The main set is designed for operation either as an independent unit or in parallel with the Hydro Board's network. When supplying current to the network an automatic constant load-control device will come into operation.

The Turgo-driven unit is coupled to an 82 kW 415 V Bruce Peebles induction generator and is fitted with a hand-operated needle nozzle which can be adjusted to pass the exact amount of compensation water required. There is no governor, but the turbine is equipped with a simple form of weight-operated overspeed trip which deflects the jet from the runner in the event of complete load rejection. A picture of this turbine in the maker's works will be found on page 131 of our April issue.

The station will also house the necessary 11 kV switchgear and at the rear will be the transformer which will step up the outgoing current to 33 kV. A subsidiary 11 kV line runs to the south while the 33 kV supply is tapped into the grid to the north. It is estimated that 9 million kWh will be generated annually. The published cost of the scheme is £458,000. This sum includes the cost of a road diversion which has been necessitated by the works and which affects about half a mile of the existing Oban-Lochgilphead road alongside the headpond; it also includes the cost of reconstructing a road bridge over the Oude river.

An interesting sidelight of the scheme is that a cave was uncovered during excavations for the downstream portal of the two pressure tunnels beneath about 20 ft. depth of rock scree, and in it bones and teeth, together with flints and quartz chips, were found. These were examined by archaeologists who expressed the opinion that the finds were of the Mesolithic period dating from about 5000 to 3000 B.C. It is anticipated that other interesting finds will come to light when the cave is further excavated on completion of the scheme.

Work was commenced on the scheme in August, 1953, and it is expected to commission the station in the autumn of 1956.

The contractors for the Oude works, including dam, tunnels, pipeline and generating station and Loch-na-Sreinge works, are R. J. McLeod (Contractors) Ltd., Glasgow, and Wm. Arnott McLeod & Co. Ltd., Edinburgh, executed the Loch Tralaig works. Messrs. P. L. J. Heron, Fort William, undertook the highway diversion and bridge reconstruction.

We thoroughly enjoyed our visit to this scheme, which, although small, is of exceptional interest in showing how a relatively small catchment can be economically harnessed to contribute a very useful block of energy to the district in which it is situated, thus saving transmission lines and helping to meet demands for power approaching the insatiable. Our thanks for permission to collect these data are due to the North of Scotland Hydro-Electric Board, who kindly made arrangements for us to inspect the scheme, and to Mr. T. J. K. Meikle, of Messrs. Kyle & Frew, of Glasgow, the Consulting Civil Engineers for the scheme, who conducted us over the site, and who supplied much of the information contained in this article. The Consulting Engineers for the electrical and mechanical sections of the scheme are Messrs. Strain and Robertson, Glasgow.

Institution of Civil Engineers Conversazione

At the Annual Conversazione of the Institution of Civil Engineers, more than 200 models and plans were exhibited of work being undertaken by British engineers in Great Britain and throughout the world. The variety of work represented was so wide that it was only to be expected that exhibits of direct hydro-electric interest should be in a minority, but this was amply compensated by quality of interest. A picture of Dokan dam, exhibited at the Royal Academy in 1956 and drawn by Mr. Adrian Montagu, F.R.I.B.A., was an apt reminder of the outstanding contribution to arch-dam analysis made in the paper presented last session by Professor Allen, Miss Chitty, Professor Pippard and Dr. Severn, summarising an investigation undertaken on behalf of Messrs. Binnie, Deacon and Gourley. Another important paper—by Mr. Paton of Messrs. Babtie, Shaw & Morton on the Glen Shira project—was followed up by the exhibit of a model of the main dam of this major development of the North of Scotland Hydro-Electric Board. The model of the hydraulic machinery building of the Mechanical Engineering Research Laboratory, East Kilbride, which was recently on view at the Institution of Mechanical Engineers, as noted in our June issue, was also included among the exhibits. Other exhibits coming within our purview included an apparatus for measuring pore-water pressure of a soil during the triaxial compression test, shown by M. G. R. Smith, M.B.E., M.I.C.E., Chief Civil Engineer, British Railways, Western Region, and an apparatus for continuously recording physical phenomena on a logarithmic time scale, applied to the measurement of concrete shrinkage, exhibited by the Cement and Concrete Association.

Aerial Surveying. A leaflet from Hunting Aerosurveys Ltd., 29 Old Bond Street, London, W.1, gives some idea of the value and possibilities of aerial photography for conducting geological surveys. The text is supplemented by some remarkable photographs, from one of which a geological map of a river system has been produced.

The 1956 CIGRE Conference

We conclude our summary of the papers given at the recent sixteenth International Conference on Large Electrical Systems.

PART TWO

THE papers on high-voltage cables showed that there is increasing interest in the possibility of using plastic insulation, and in papers by Messrs. Otto Gasser, and Christian Held, of Siemens-Schuckertwerke A.G., and Herbert Pairitsch, of Felten und Guilleaume, the authors showed that the dangers of inflammability with polyethyline and P.V.C. are no higher than that with the cable types already in use, while the cables are stated to be resistant to ageing and corrosion. P.V.C. insulated cables have been manufactured for voltages up to 20 kV, and there seems to be a promising field for development to further fields of utilisation.

In the papers relating to the more normal types of cable, in which gas or oil pressure is used, the outstanding achievement described at the Conference was that of laying the all-aluminium 301 kV cable for the connection to the Mount du Bose power house, close to the outlet of the Kemano River in Canada. This cable, designed to transmit the load of two 140,000 h.p. impulse turbines from an underground power house, comprises three single-conductor cables per circuit racked in an underground tunnel, finally rising to a cable terminal adjacent to the high-voltage transformers. The cable employs a hollow aluminium segmental conductor, and the insulation thickness is 1·09 in. radially, the diameter of the complete conductor being 3·85 in.

In the papers on towers and tower foundations the main focus of interest was on the subject of over-designing and its economic implications. The questions were whether the safety factors employed were too high, and whether it was possible to bring a greater degree of accuracy into the calculations relating to the stresses in overhead lines under service conditions. The excellent tower-testing organisations, particularly those in Italy, were described, and the contribution they could make to the progress of overhead-line design was noted. Testing stations for towers have existed for some years at Hereford, in England, and (in relatively recent times) at Saint-Quentin, in France.

Overhead Lines

The general overhead-line section included an extremely fascinating description of the crossing of the Messina Straits to couple the water-power systems of the Italian mainland to the Island of Sicily. This project, with the very large-size conductor (of a total diameter of 26·80 mm.) running across the span of 3,450 m., one of the longest spans in the world, was completed towards the end of 1955, and the author of the report, Mr. G. Silva, of Italy, the Director and General Manager of CONIEL, the enterprise responsible for the project, was congratulated on its successful completion. Other papers in this section indicated an increased interest in aldrey conductors, and some authors felt that the steel-cored aluminium conductor might be superseded by various alloy or all-aluminium types of cable in the relatively near future. The calculation of ice and wind loading was seen to be a matter on which much research is still necessary, and a number of papers dealt with this subject. The actual laying and tensioning of conductors of very high-voltage lines is a subject which has not before been prominent in CIGRE discussions, and it is obvious that the necessity to avoid damage to the conductors on the one hand, and to speed up the stringing operation on the other, is leading to a renewed focus of attention on this subject.

Little new emerged from the insulator discussions, except the fact that there is little uniformity between national practices in regard to the testing of insulators in the course of manufacture, and it was thought that much more might be done to secure uniformity in this respect.

The section on protection and relaying did not bring forward anything especially new, although it is obvious that very great detailed study is taking place into protective-gear problems in many countries. There was seen, however, a tendency towards the use of microwave radio for the control of high-voltage transmission circuits, and it appears that such radio links are becoming steadily more reliable. The problem of securing space in the radio-frequency bands is to some extent overcome by the use of the highest possible frequencies, but this may form a limiting factor. Experience in America, as detailed by Mr. Glover P. Fallon, of the Baltimore Gas and Electric Company, showed that the radio spectrum in the vicinity of 960 Mc/s is most suitable for microwave operation, but he went on to say that the manufacturers of communication equipment needed further education in the type of reliability and continuity of service needed for electric power-system relay applications.

The Study Committee of CIGRE on this subject had asked the National Committees to obtain operational statistics for protective-gear equipment used in various countries, and the results of this work were summarised in a lengthy report which should prove extremely valuable to those working in this field. Incorrect operation of protective gear has been closely analysed, and it is seen that reliability, in general, is of a very high order.

System Stability and Control

In the system-stability and voltage, power, and frequency-control section the papers showed that there is obviously an increase in the use of automatic frequency control, while network analysis studies are being undertaken on more and more networks to give

exact knowledge of such matters as tie-line power control in large networks, unbalanced conditions arising from single-phase loads, and recovery voltages during fault clearing on long transmission lines with series capacitors. In this last aspect of the subject series capacitors for increasing the power transfer capacity of large networks are coming into increasing use, and a Swedish paper by Messrs. Ahlgren and Grundmark, of the Swedish State Power Board and ASEA respectively, dealt with the 380 kV series capacitors recently installed and to be installed on the Swedish network. The problem with series capacitors has always been the protection of the circuits in which they are fitted, and the authors state that it is desirable that large-scale series-capacitor installations should remain in service immediately after a short circuit. This means that the capacitor must be able to withstand the overvoltages resulting from short circuits, or else the capacitor, if it has a lower withstand voltage, must be used in combination with a self-extinguishing spark-gap device. The quenching gap appears to the authors to be the only solution, and the paper deals with the design of such gaps for 380 kV service.

Extra-High-Voltage Transmission

The extra-high-voltage a.c. transmission line section was of interest for three reasons. First, it was shown that the voltage of 380/400 kV is becoming increasingly common, and is now employed in Sweden and Russia, while Finland, France and Germany expect to have 380 kV lines in commission within the next two years. The problems of radio interference appear to have been solved, possibly through the almost universal adoption of bundle conductors. This question formed the subject of much controversy at the CIGRE meetings in the last four years, but with the exception of an American engineer, who said in the discussions that single conductors might still be used up to 330 kV, it appears universal practice to employ the two- or three-conductor design when stepping up from 220 kV to 275 kV and beyond.

The second peak of interest in this section was the full description of the Russian line, extending over 1,000 miles from Kuibishev to Moscow, and capable of transmitting a power of 1,150 MW. The major part of this line was switched in during the spring of this year, and, as it happened, a party of Central Electricity Authority engineers from Great Britain, headed by Lord Citrine, the Chairman, were present at the ceremony. This line has three conductors per phase located at the apices of an equilateral triangle with a 400 mm. side. The steel-cored aluminium conductor has 54 aluminium strands and 19 steel strands, each aluminium strand being 3·37 mm. in diameter, and each steel strand 2mm. The air-blast circuit breakers in the substations have a current rating of 2,000 A, and an interrupting capacity of 10,000 MVA, the clearing time being three cycles.

Finally, there was a most interesting report from Sweden in which, for the first time, an examination was made of the possibility of raising transmission voltages still further, from the present highest level of 380/400 kV to 650 kV. The paper by Messrs. Jancke and Lalander said that investigations had shown this voltage to be the highest practicable figure in the present state of technical progress, but it was felt that although there was a pressing need in Sweden to reinforce yet again their extensive power system, bringing in water power from the north to the industrial regions of the south, it was considered that the cost of the extensive development work needed for an increase of pressure to this very high figure would not be justified in the case of a relatively small overall power economy such as that existing in Sweden. It was therefore decided to investigate the possibilities of using 500 kV, and here the authors showed that relatively little alteration to the present 400 kV system would make it possible to use existing structures for 500 kV operation. It was therefore proposed that investigations on a detailed basis should be carried out into the possibility of a changeover in the future of the Swedish super grid to the 500 kV level; and the report which may well be provided at the 1958 CIGRE meeting on this subject will no doubt be awaited with very considerable interest.

High-Voltage Direct-Current Transmission

So far, in this survey of the CIGRE papers we have concentrated on the papers themselves, and have not touched to any great extent on the discussions. In general, the many speakers of all nationalities who took part in the discussions of the foregoing papers did not disagree with the conclusions reached by the various authors. There was much elaboration of the papers by the authors themselves, but it could not be said that there was any great amount of true debate, in the sense of questions being posed and then answered. In the final section in this brief survey of the 1956 CIGRE Conference, however, the discussion did add very considerably to the material contained in the papers. It related to the use of extra-high-voltage direct current for power transmission.

The interest in high-voltage d.c. has waxed and waned in recent years, but this subject evoked very great interest at the recent CIGRE meeting. This was perhaps mainly due to the presence of a paper by the Russians, who described an experimental line, 112 km. long, extending from Kashira to Moscow and operating at 200 kV d.c. We learned for the first time that this line has been in operation successfully for over 5 years, transmitting over 600 million kWh during that period. Moreover, the Russians have a Direct Current Institute at Leningrad in which some 500 engineers are engaged in research work in this field. A quotation from the paper may be of especial interest. It ran, "Power development in the U.S.S.R. and the necessity of utilising water-power resources remote from the centres of distribution has put forward the problem of the transmission of large quantities of power over long distances. The use of high-voltage direct current for long-distance transmission is stimulated by the great possibilities offered by this system, and its fundamental advantages as compared with alternating-current transmission." The Russians, in the discussions and in the paper itself, said that a new long distance d.c. line operating at 400 kV was under construction, and should be completed by 1960. It was designed to interconnect the Stalingrad hydro-electric plant with the Donbass and the South power systems. Further, with the experience gained on the Kashira line and the new Donbass scheme, they hoped to be able to plan very long-distance lines, over 1,000 miles in length, to enable them to bring in to European Russia the unexploited resources in Siberia.

Sweden has been a pioneer in high-voltage d.c., and

(Continued on page 302)

Fig. 1. Isohaara power station at the mouth of Kemijoki river

Development of Water-Power Resources in the North of Finland

Professor V. Veijola, Managing Director of Electrical Inspectorate, Finland, presents a picture of the power situation in his country, and gives an account of the plans now in course of execution for harnessing the Kemijoki river in Northern Finland. When fully developed, the main riverbed should produce 3,700 million kWh per annum, and the tributaries at least another 1,500 million kWh

IN the article on the general aspect of hydro-electric developments in Finland published in WATER POWER, April 1952, it was pointed out that after the year 1954 construction of new larger water-power plants would be carried out exclusively in the North of Finland, because almost all the water-power resources located in the South and Middle Finland are now harnessed. Being aware of this fact we have for several years carried out comprehensive investigations in order to find out the most economical solutions for the harnessing of the water-power resources of northern Finland, or Lapland as it is also called. These investigations have been executed in extremely difficult conditions in the tremendously wide unpopulated and not easily accessible areas of Lapland, partly in the arctic cold. All the modern technical methods such as aerial photography, seismic investigations, helicopters, etc., have been applied in the work. Although the investigations carried so far have not yet crystallised the development plans for the whole area, the construction programme, for the main river of the area, the river Kemijoki, can be regarded as final.

In order to fill in the background for the development plans of the water-power resources in the North of Finland we shall first discuss the present stage of electrical-energy production in Finland and the estimated development of the next few years in the consumption of electrical energy in this country.

Development of Production and Consumption of Electrical Energy

Fig. 2 gives a diagrammatic representation of the annual total production of electrical energy in Finland during the period 1930 to 1954, i.e. the period during which Electrical Inspectorate has collected the statistical data relating to the country's electrical supply undertakings. From the diagram the rapid development of the economic life in Finland in the 1930's, and the difficult period during the war and the few subsequent years can be clearly seen. Exceptional water shortage in 1947-1948 made the situation still more difficult, and the country was faced with a very severe shortage of electricity. During the last seven years, with the exception of the year 1952, the economic life in Finland has developed very favourably and in consequence the production and consumption of electrical energy has almost doubled during these seven years. Thanks to energetic construction work on new water-power plants the consumption of electrical energy has just been met. It may be mentioned that the total installed capacity of water-power plants which remained to Finland at the armistice in 1944 amounted to 415,000 kW, producing 2,500 million kWh per annum. At the end of 1954 the total capacity of our water-power plants was 980,000 kW and during 1955 the 1,000,000 kW mark was passed. At the same time the annual production exceeded 6,000 million kWh, partly because of the exceptional water abundance during the first part of the year 1955.

In order to ascertain the future demand for electrical energy of the country a far-reaching advance estimate was made for the five-year period 1954-1958. This estimate was directed to all consumers whose consumption exceeded or would probably exceed the limit of 500,000 kWh during the period. The advance estimate was extended roughly to the five-year period 1959-1963 as well. Fig. 3 shows how the estimated energy demand will develop by the year 1963 and how it will be met by water power and thermal power in accordance with the present plans. In 1958 the energy demand will amount to 8,300 million kWh, some 6,000 million kWh of which will be met by water power under normal conditions of drainage. During the year 1962 the water-power generation will amount to nearly 10,000 million kWh according to present plans; in other words, the total output of that time will mean almost double output compared with the present stage.

Water-Power Resources of the North of Finland

For the time being, it is estimated that the theoretical total water-power resources of Finland amount to 30 milliard kWh, and at least half of them, viz. 15 milliard kWh, are technically available for harnessing. Of this amount about one third is located in the south and central parts of the country where the overwhelming majority of the population live and where all the biggest industrial centres and towns are situated. The remaining two thirds of our technically available hydraulic resources are located in the North of Finland in the area north of the river Oulujoki whence the distance to the most important consumption centres is about 800 km. The average height of the ground in northern Finland varies between 100 and 200 m. reaching 300 m. at the upper courses of some rivers. In general, the terrain of the

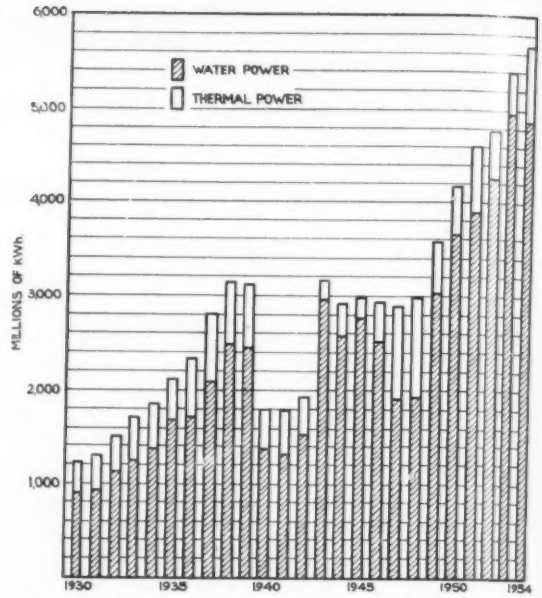


Fig. 2. Annual total production of electrical energy in Finland during the period 1930 to 1954

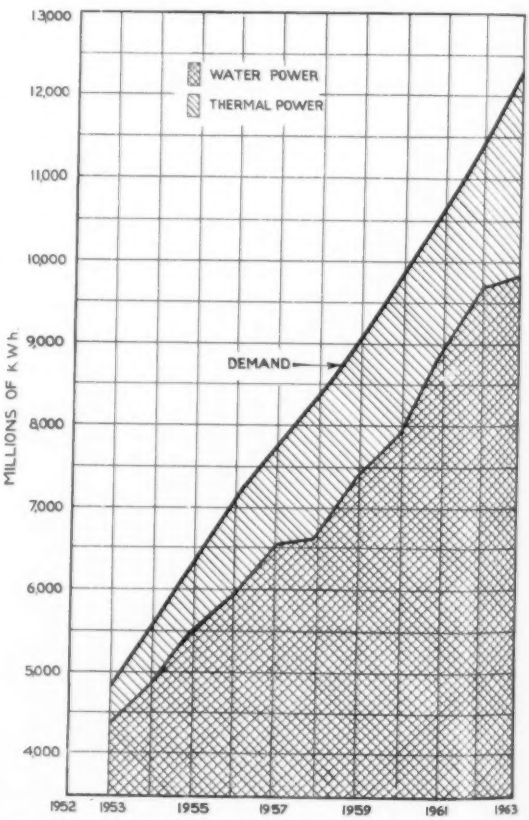
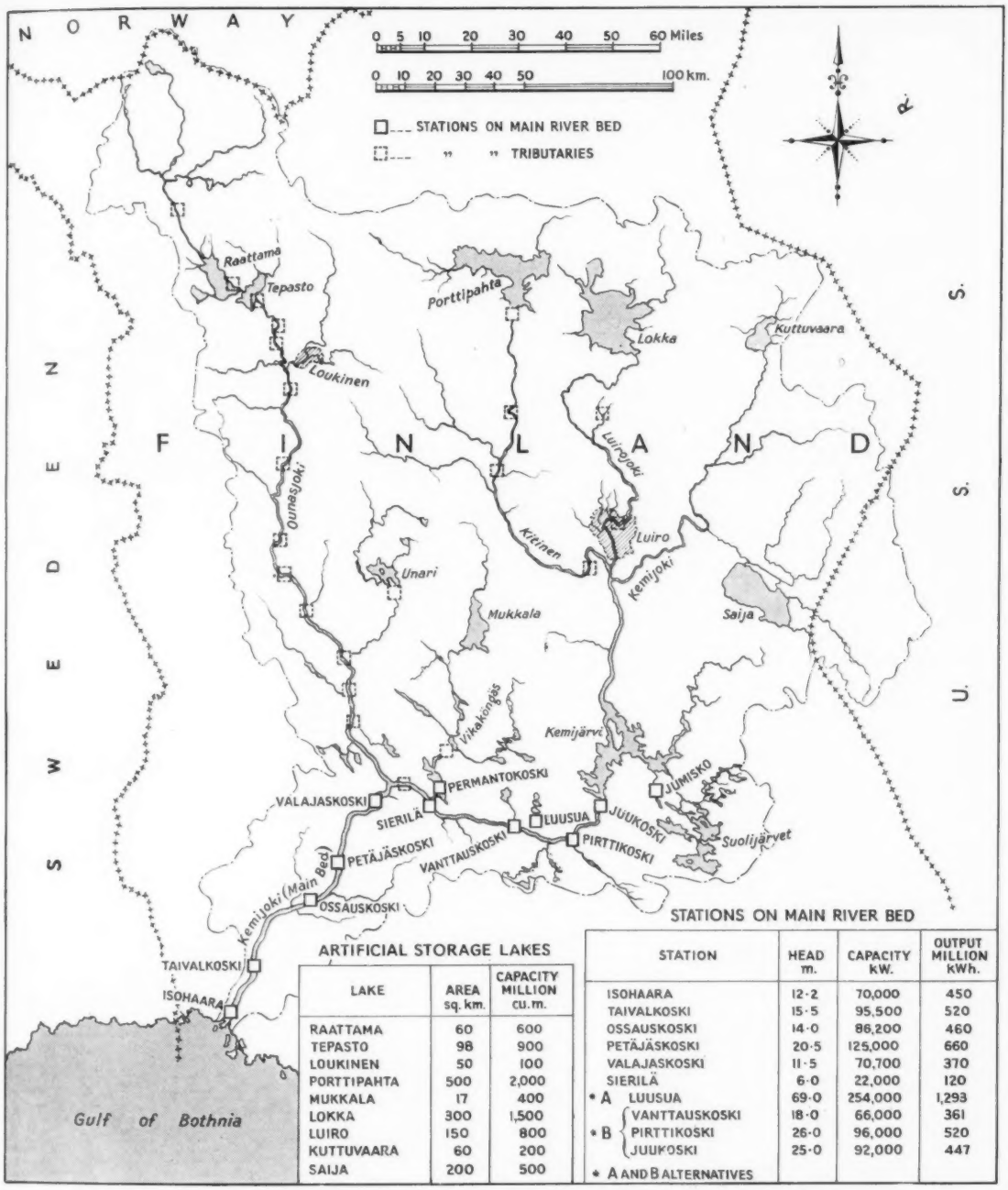


Fig. 3. Estimated annual total consumption and production of electrical energy in Finland by 1963



ARTIFICIAL STORAGE LAKES

LAKE	AREA sq. km.	CAPACITY MILLION cu. m.
RAATTAMA	60	600
TEPASTO	98	900
LOUKINEN	50	100
PORTTIPAHTA	500	2,000
MUKKALA	17	400
LOKKA	300	1,500
LUIRO	150	800
KUTTUVAARA	60	200
SAIJA	200	500

STATIONS ON MAIN RIVER BED

STATION	HEAD m.	CAPACITY kW.	OUTPUT MILLION kWh.
ISOHAARA	12·2	70,000	450
TAIVALKOSKI	15·5	95,500	520
OSSAUSKOSKI	14·0	86,200	460
PETÄJÄSKOSKI	20·5	125,000	660
VALAJASKOSKI	11·5	70,700	370
SIERILÄ	6·0	22,000	120
* A LUUSUA	69·0	254,000	1,293
* B VANTTAUSKOSKI	18·0	66,000	361
* B PIRTTIKOSKI	26·0	96,000	520
* B JUUKOSKI	25·0	92,000	447

* A AND B ALTERNATIVES

Fig. 4. Development scheme for the hydraulic resources in the North of Finland

area is sparsely settled hilly fell terrain, and tremendous forest and swamp districts which are almost uninhabited. Water courses in Lapland, contrary to those of south and central Finland, are particularly poor in lakes, from which it follows that the seasonal variations in the river discharge have a very extensive range. In the spring, when snow and ice melts on the fells and in the valleys, the overflow may reach ten times the average flow, whereas during the winter months the flow may decrease to one fifth of the average. This phenomenon, of course, is not unique to the rivers of Lapland, but is very common, e.g. in the rivers of the Swiss and Norwegian mountain districts. However, in mountain districts it is often quite easy to dam the deep gullies to obtain reservoirs with high water capacity by means of which the regulation of run-off, necessary for the rational operation of power plants, can be achieved. In northern Finland, on the other hand, the harnessing of water power is made difficult by the fact that the area in question is not properly a mountain district with deep gullies in which high-capacity

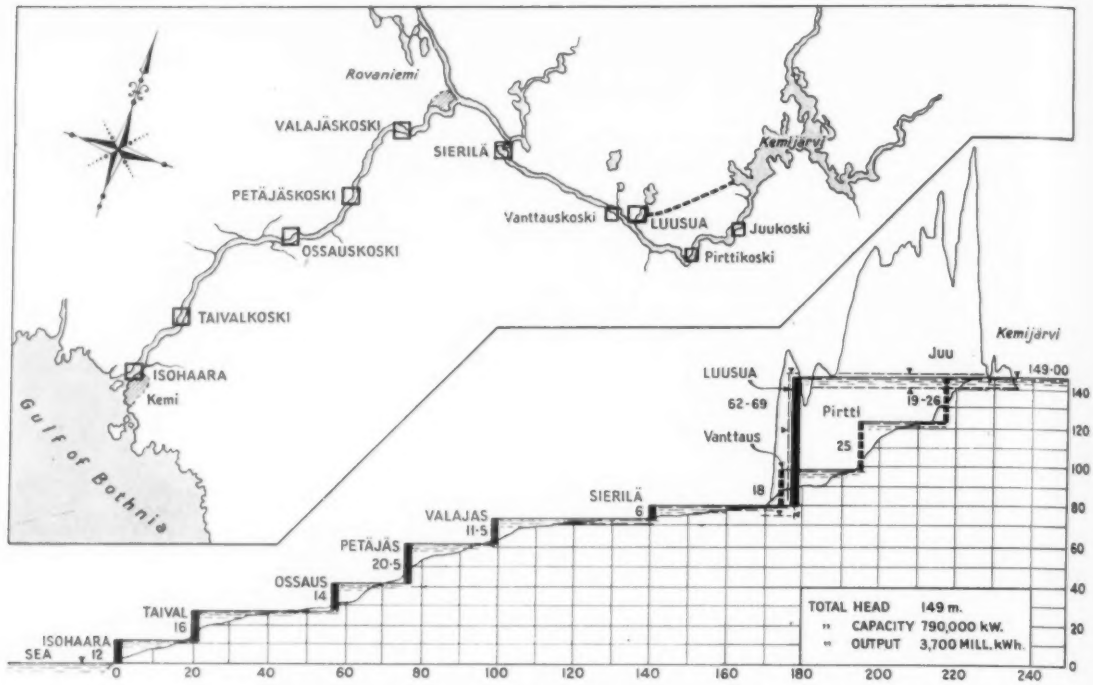


Fig. 5. Map and profile of the Kemijoki main river-bed development

reservoirs can be created, and we are obliged to dam comparatively shallow artificial lakes with tremendous superficial areas in order to make the construction of economical power plants possible. Due to the wilderness character of the area this is practicable, but the extensive damming works involve very high costs.

Kemijoki Development

The most important hydraulic power source of northern Finland is formed by the river Kemijoki, which is the longest and most powerful river in the whole country. The sources of the Kemijoki river are in the fell terrain adjacent to the boundary between Finland and the U.S.S.R., almost 200 km. to the north of the Arctic Circle. It flows from there through the unpopulated wilderness, obtaining several tributaries from the fells of Central Lapland. Near the Arctic Circle the Kemijoki river reaches the central lake of the watercourse, Lake Kemijärvi, which has a surface of 142 sq. km. at an altitude of 149 m. above sea level. From Lake Kemijärvi the river continues to the west towards Rovaniemi, the economic centre of northern Finland, where the biggest tributary, the river Ounasjoki, joins the main river. From Rovaniemi the Kemijoki river flows south-west a distance of about 100 km. reaching finally the Gulf of Bothnia. The length of the main fork of the Kemijoki amounts to 512 km. The average water flow between Lake Kemijärvi and Rovaniemi is 300 cu. m. per sec. and at the lower course about 530 cu. m. per sec. Owing to the lack of lakes in the catchment area, the seasonal variations in the water flow are very great, the highest overflow being about 4,300 cu. m. per sec. whereas the lowest measured flow during the winter months has gone down to 90 cu. m. per sec. According to present estimates the energy resources of the Kemijoki main riverbed amount to 3,700 million

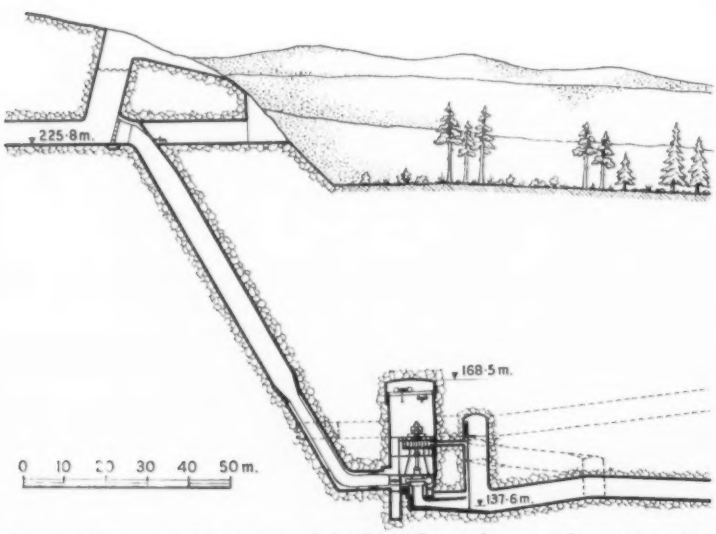


Fig. 6. Diagrammatic section of the Jumisko underground power station, containing one 30,000 kW unit operating under a head of 96 m.

kWh per annum and the resources of its tributaries, still partly uninvestigated, are at least 1,500 million kWh, which together correspond approximately to the total amount of hydraulic power developed so far in the whole country.

The best picture of the development projects of the hydraulic resources in the Kemijoki catchment is given by the Figs. 4 and 5. Fig. 4 shows the development project of the entire catchment, which involves the construction of some 30 power plants and the damming of nine artificial reservoirs. The total surface of these reservoirs amounts to no less than 1,500 sq. km. and the total capacity to 7,000 million cu. m. It may be mentioned that the biggest of these planned artificial lakes, Lake Porttipahta, will have a surface of 500 sq. km. and a capacity of 2,000 million cu. m. which means an average depth of 4 m. only. The entire development project shown in Fig. 4 cannot yet be regarded as final in all details.

Fig. 7. View of Jumisko remote-controlled unit inside the mountain

On the other hand, the development project for the main riverbed between Lake Kemijärvi and the Gulf of Bothnia, shown in Fig. 5, can be considered as final. According to this scheme the total head from Lake Kemijärvi to the Gulf of Bothnia will be divided among seven or alternatively nine power plants, the first alternative involving the combination of the heads of the three first rapids counted from Lake Kemijärvi. This combined head of 69 m. applied in the Luusua power plant would produce a capacity of 254,000 kW and an output of 1,293 million kWh, which would mean the biggest waterpower plant in this country. However, this alternative will probably not be realised owing to difficulties in capital investment.

At the present moment one of the power plants on the Kemijoki river main bed is in operation, i.e.

Fig. 8. General view of the Petäjäs koski power station site on the Kemijoki river. Regulation dam under construction

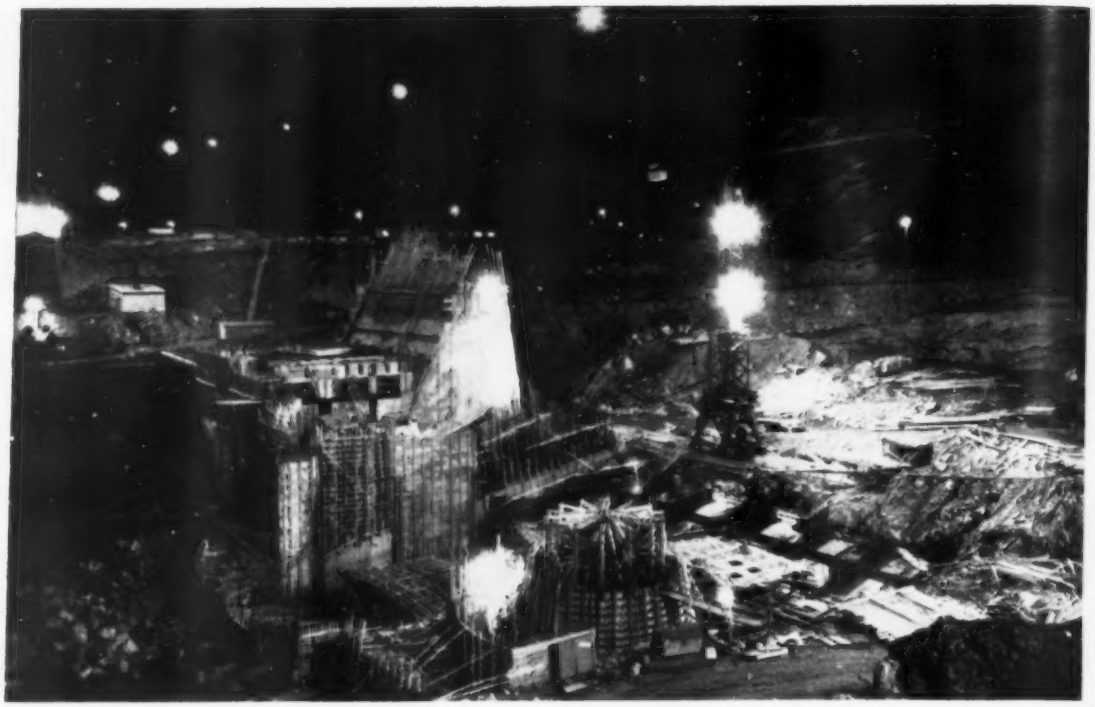


Fig. 9. A night view of the construction of the Petäjäskoski power station

Isohaara plant at the mouth of the river (Fig. 1). This power plant was constructed by the private power company, Pohjolan Voima Oy, and it has now two units of 23,000 kW, each operating on a head of 12·2 m. and producing 275 million kWh per annum. The maximum usable flow of the station is 460 cu. m. per sec. After the regulation of the water flow in the Kemijoki river the third unit will be put into operation and the output of the station will increase to some 450 million kWh per annum.

Pohjolan Voima Oy has also constructed another power plant in the Kemijoki catchment area, i.e. Jumisko plant (see Figs. 3, 6 and 7) situated near the south coast of Lake Kemijärvi and having an outlet channel directly to this lake. Jumisko is the first underground power plant in Finland. It is located 50 m. belowground, operating on a head of 96 m., and its 30,000 kW unit generates 70 million kWh per annum. The Jumisko power station is fully remote-controlled from the Isohaara station situated some 180 km. to the south-west. After the completion of a pumping station in connection with the Jumisko plant the output will increase to 100 million kWh per annum.

In addition to the above-mentioned two power plants already in operation, a third power plant, Petäjäskoski, is in course of construction. This power station is being constructed by the state-controlled power company, Kemijoki Oy, which was established especially to develop the hydraulic power resources in the Kemijoki river. Kemijoki Oy operates on the same basis as the other state-controlled power companies: Imatran Voima Oy and Oulujoki Oy, established earlier. It is a joint-stock company formed by both the State and private water-rights owners in which, however, the State, as the biggest water-rights owner in the Kemijoki river, has the share majority.

Petäjäskoski power station will be the biggest power plant in the lower course of the Kemijoki river. The total capacity of its three units will be 125,000 kW, operating on a head of 20·5 m. and producing some 660 million kWh per annum. Figs. 8 and 9 give an idea of the construction works of this station. The first unit of the Petäjäskoski station will be put into operation in course of 1956.

Kemijoki Oy has the intention to put every year a new power plant in the Kemijoki river under construction. Consequently, during the forthcoming ten years, three power stations will simultaneously be in course of construction. Damming works of the artificial storage lakes will be started simultaneously with the construction of power plants, in order to be able to start the far-reaching regulation of the run-off in the Kemijoki catchment when the power stations are completed with the total number of units.

Transmission from Kemijoki to Southern Finland

As was previously mentioned, all the most important industrial centres and towns are located in the south and central parts of the country, to which the distance from the energy sources in northern Finland is of the order of 800 km. Consequently, the arrangement of a large-scale power-transmission system from north to south is inseparably connected with the development of the power resources in the north of Finland.

The transmission systems from north to south include at the present moment two 220 kV lines from the power plants on the river Oulujoki to south Finland up to Helsinki, and one 110 kV line from the Isohaara power plant on the Kemijoki river along the

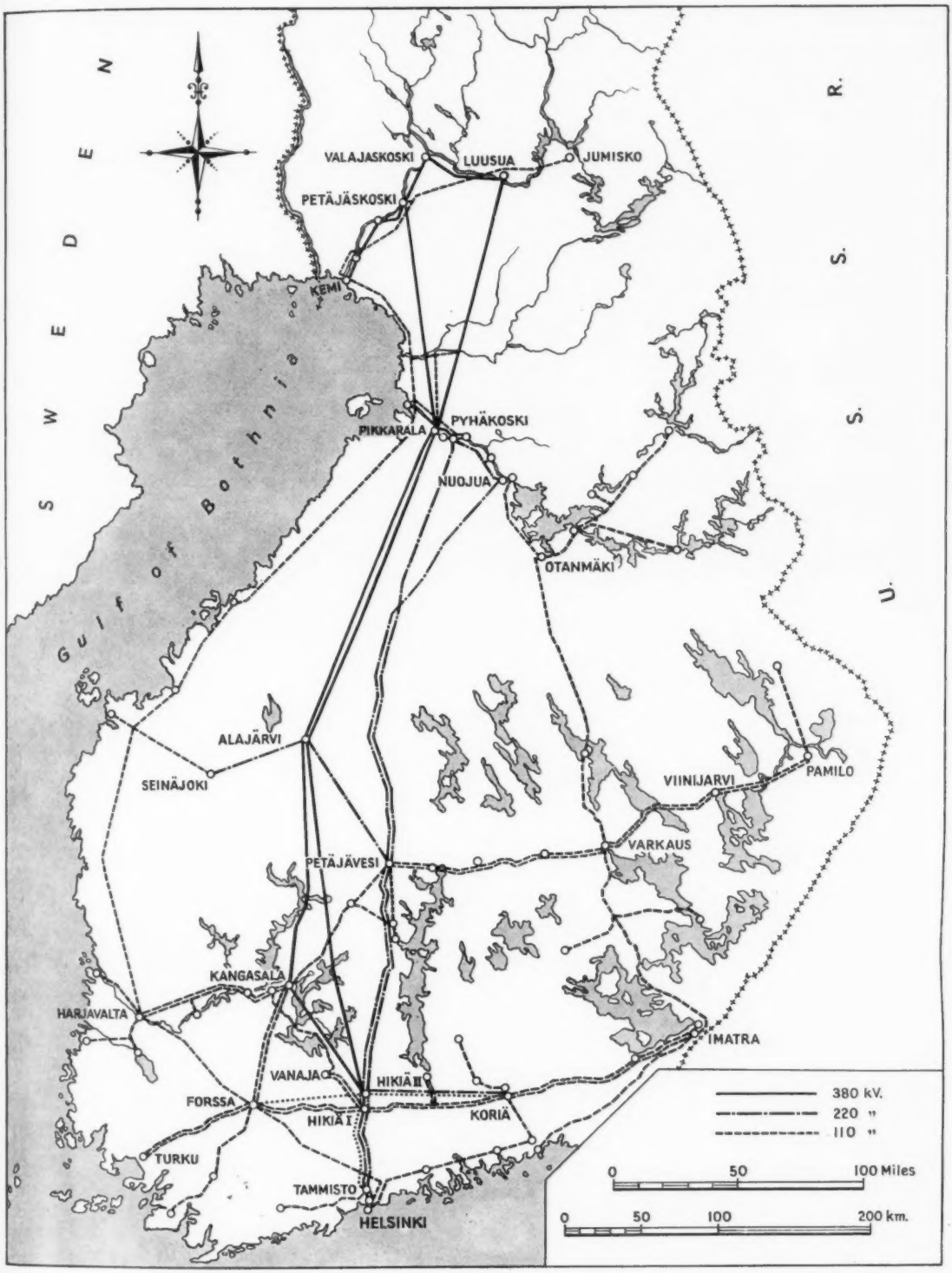


Fig. 10. Schematic map of Finland showing the most important lines of the future long-distance transmission in Finland. The 380 kV system is under construction; the other lines are mostly in service

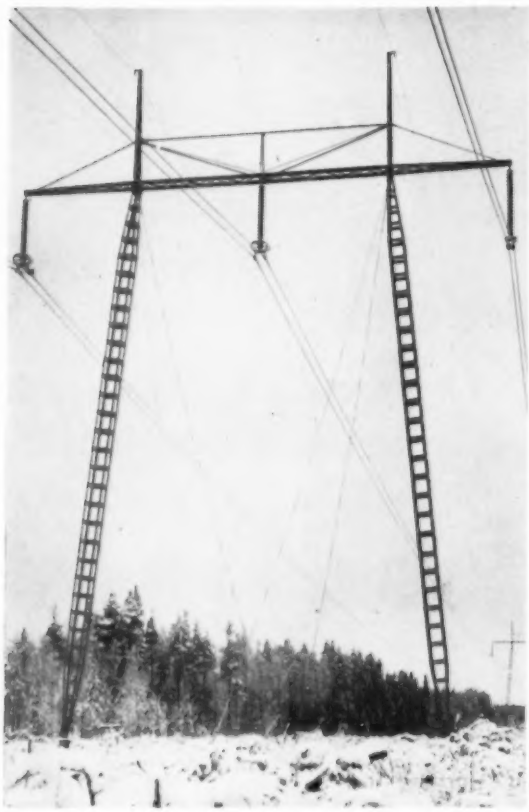


Fig. 11. Part of the 380 kV line from Petäjäskoski to South Finland

coast district of the Gulf of Bothnia to southern Finland. In order to determine the most advantageous transmission system a comprehensive investigation of the problems involved in transmitting energy from the new Kemijoki power plants to southern Finland was carried out, 220 kV and 380 kV systems being the alternatives under consideration. The investigations showed that the latter alternative—the 380 kV system—was slightly more economical than the highest system voltage, 220 kV, applied hitherto. The especially small transmission losses were considered to be a special advantage of the 380 kV system—a fact of great importance in a country poor in energy. For transmitting the whole capacity of the Kemijoki hydraulic resources two 380 kV lines will be sufficient, whereas a 220 kV transmission system would require eight parallel lines. In consequence, the construction of 380 kV lines will not waste forests, the most important sources of raw material for our country, to anything like the extent of a 220 kV system. Fig. 10 shows the most important lines of the future long-distance transmission in the 380 kV, 220 kV, and 110 kV systems in Finland.

The first section of the 380 kV transmission system, the line from the Petäjäskoski power station to the Alajärvi transformer substation, about 400 km in length, is now under construction, and a view of this line is seen in Fig. 11. Special mention may be made of the light construction of the steel towers. Each phase conductor in this line is composed of two steel-cored aluminium cables, construction Finch (C.E.S.A.), cross-sectional area 635 sq. mm. and weight 2·1 kg. per m. The distance between these two cables is 45 cm. Above the phase conductors two earth wires are run which consist of steel-cored cables each with a cross-sectional area of 70 sq. mm. The first 400 km. section of the 380 kV line will be completed in the course of 1956 and it will be connected to the existing 220 kV system at the Oulujoki river and at the Alajärvi transformer substation. By means of this first 380 kV line, together with the existing 220 kV system, a capacity of 800 MW can be transmitted to South Finland. When the second 380 kV line is completed the transmission capacity of the system will be doubled to 1,600 MW, and at the final stage, after connecting series-capacitors in the transmission system, a further increase up to 2,000 MW will be achieved.

Economic Outlook

Development of the hydraulic resources in the North of Finland is an enormous undertaking in the circumstances of our four million people, and it is not an easy question to find capital for this investment because we have simultaneously to finance many other objects which are of vital importance to the nation's livelihood. The first part of the development programme now in progress—construction of the power stations on the Kemijoki main river bed, damming of artificial storage lakes, and construction of the necessary 380 kV transmission system—will alone demand an investment exceeding £100,000,000. On the other hand, the rapid realisation of this development programme is an absolute necessity in order to ensure in this country the continuous progress of industry and economical life in general. At the same time, realisation of the hydraulic development programme will create in the barren North Finland possibilities to embark on industrial and other economical activities on quite another scale than hitherto.

From page 294

again in the discussion the engineers from that country were able to report satisfactory operation of the Sweden-Gotland submarine cable, which has now been in commission for two years. Further, they said that they expected to change over some of their 220 kV lines (now 3 phase a.c.) to direct current, in order to increase their transmission capacity. In the discussions at the Conference there were indications that the proposed cable across the English Channel, first mooted as an a.c. scheme, is now to operate on d.c.; and the Japanese also brought forward d.c. projects for coupling in to the mainlands the hydro power on the various islands of Japan. There was renewed interest, also, in the possibility of using d.c. for the proposed cable across the Cook Strait between the South and North Islands of New Zealand, to even out the disparity between the unexploited water-power resources in the two islands.

CIGRE, 1956, was a larger gathering than ever before, and in spite of the fact that new regulations have been made so that there are fewer simultaneous discussions and fewer subject headings, the press of technical information seemed to be as great as ever.

Quicker Design of Penstocks

The author outlines a method for shortening the lengthy computations required for determining the most economic design of penstock

By Dr. Eng. Harald Tults, A.M.A.S.C.E.

COMPUTATIONS by the cut-and-try method of the economic diameters of a stepped penstock, for which the sum of the annual costs of the penstock and of the power loss due to the hydraulic factors is minimum, are time consuming. Somewhat less mathematical work is involved when using equations as those by Charles Voetsch and M. H. Fresen ("Economic Diameter of Steel Penstocks," ASCE Transactions No. 107, 1937, p. 89). However, the solutions of their Eq. 22, p. 93 by trial are still too long for a multiple stepped penstock, particularly during the preliminary studies.

Fig. 1 shows a section of a penstock of uniform diameter. The pressure head increases toward the power house because of the water-hammer effect. The hydraulic losses consist of the local losses at the beginning of the section, as intake or contraction and bend losses, and of the friction loss in the section.

For a certain diameter of the pipe, the thickness of its shell and therewith the cost of a unit length of the penstock is directly proportional to the head on each section. Thus, it is sufficient to compute the annual costs only for a unit length of the average thickness in the middle of a straight penstock section of uniform diameter.

Considering the power loss caused by the head loss in the penstock, the cost of lost power may also be computed for the unit length, when the local losses, which are proportional to the velocity head, are distributed uniformly as an equivalent friction loss on the whole length of the section (Fig. 1).

Using the Manning formula, the equivalent friction slope may be written as:

$$\frac{k}{L}\frac{V^2}{2g} = s_f \frac{kD^{4/3}}{184{\cdot}95\ n^2L} \quad \text{.....(1)}$$

k = sum of coefficients of local losses as a ratio of velocity head;
V = average velocity in a section of diameter D;
L = length of penstock section;
g = gravitational acceleration;
s_f = friction loss in unit length of penstock;
D = diameter of pipe, in feet;
n = friction coefficient, in Manning formula.

The total annual cost of 1 ft. of penstock in the middle of a straight section of uniform diameter may be written as follows:

$$C_p = A\frac{Q^3}{D^{5\frac{1}{3}}}\left(n^2 + \frac{k}{184{\cdot}95L}D^{4/3}\right) + BHD^2 \quad \text{.....(2)}$$

A and B are constants and valid for all sections of a particular penstock:

$$A = 3465{\cdot}115\ efb \quad \text{.....(3)}$$

$$B = 334\frac{ar(1+i)}{SE} \quad \text{.....(4)}$$

A = a constant of cost of annual power loss caused by the head loss in penstock;
e = overall efficiency of plant, in decimals;
f = loss factor, in decimals, corresponding to the load factor;
b = value of power loss caused by the head loss in penstock, per kWh;
Q = design discharge of penstock, in cusecs.;
H = average head on a straight section of penstock, in ft.;
B = a constant of annual cost of penstock;
a = cost of steel in penstock, per pound;
r = ratio of annual fixed, operating, and maintenance charges to construction cost of penstock;
i = ratio of overweight of steel in penstock (ring girders, supports, expansion joints, etc.), in decimals;
S = permissible stress in steel, in lb. per sq. in.;
E = longitudinal joint efficiency, in decimals.

When no other losses exist as that of friction, i.e., k is equal to zero, the economic penstock diameter could be determined without trials by equalising the first derivative of Eq. 2 to zero.

$$D = \sqrt[7\frac{1}{3}]{2{\cdot}667\frac{AQ^3n^2}{BH}} \quad \text{.....(5)}$$

As the values of A, B, Q, and n are constant for all sections of a penstock, the diameter of any section of this penstock can be determined by the Eq. 5 or by its modified form:

$$HD^{7\frac{1}{3}} = 2{\cdot}667\frac{A}{B}Q^3n^2 = \text{Constant} \quad \text{.....(5a)}$$

However, the effect of the local losses is negligible only when the loss coefficient, k, is small and the length, L, comparatively large. Otherwise, the local losses have to be considered in determining the economic penstock size, and that can be done only by trials.

The number of the trials may be reduced when Eq. 5 is used to establish the first trial size of the penstock diameter. This would be somewhat smaller than the exact economic diameter because the effect of the local losses is omitted. The exact diameter, D_t, itself can be easily determined by trial using this approximate diameter and the two next larger ones in Eq. 2.

At preliminary studies, it would be sufficient when the diameters of other sections are computed from the constant product, $HD^{7\frac{1}{3}}$, in Eq. 5a, in which D is replaced by D_t, as shown in Eq. 5b:

$$HD^{7\frac{1}{3}} = H_tD_t^{7\frac{1}{3}} = \text{constant} \quad \text{.....(5b)}$$

Thus, the effect of the local losses, additional to the friction effect in Eq. 5a, is taken into account.

To obtain more precise results, the trials for the

sections for which the ratio of the effect of local losses to friction losses: $\frac{kD^{4/3}}{184{\cdot}95L} \Big/ n^2$, deviates considerably from the corresponding ratio at the first trial computations, may be repeated.

In general, the curve of the total annual losses is rather flat near its minimum value. Besides that, the penstock sizes are rounded off to the nearest increment of the diameter. Therefore, extreme accuracy is not essential in the cost study.

To facilitate the computations, the 4/3, 2, $5\frac{1}{3}$, and $7\frac{1}{3}$ powers of diameter sizes from 5 to 15 ft. in 3 in. increments, necessary for solutions of Eqs. 2, 5, 5a and 5b, are compiled in Table 1.

After the economic diameters of a penstock are established, the shell thickness, t, can be determined.

As the shell thickness is increased stepwise toward the power house, and as this incremental increase is usually constant, only the thicknesses at both ends of a straight penstock section of uniform diameter have to be computed:

$$t_{1\cdot2} = 2{\cdot}604\frac{H_{1\cdot2}D}{SE} \quad \text{.....(6)}$$

t_1, t_2,—thickness at upper and lower end of penstock section, respectively, in inches:

H_1, H_2,—pressure head at upper and lower end of penstock section, respectively, in ft.

These exact thicknesses have to be rounded off to the next higher standard plate thicknesses.

The lengths of these end sections of standard thickness $\bar{t}_1$ and $\bar{t}_2$ are:

$$\Delta L_{1\cdot2} = \frac{\pm 0{\cdot}384\frac{\bar{t}_{1\cdot2}SE}{D} \mp H_{1\cdot2}}{s_H} \quad \text{.....(7)}$$

where:

$$s_H = \frac{H_2 - H_1}{L} \quad \text{.....(8)}$$

s_H = pressure gradient on the centreline of the penstock (Fig. 1). The upper signs, + and −, are valid for the upstream and the lower ones for the downstream end of the penstock section.

As the shell thickness of the intermediate straight pipe is increased in the direction of the power house by the constant in-

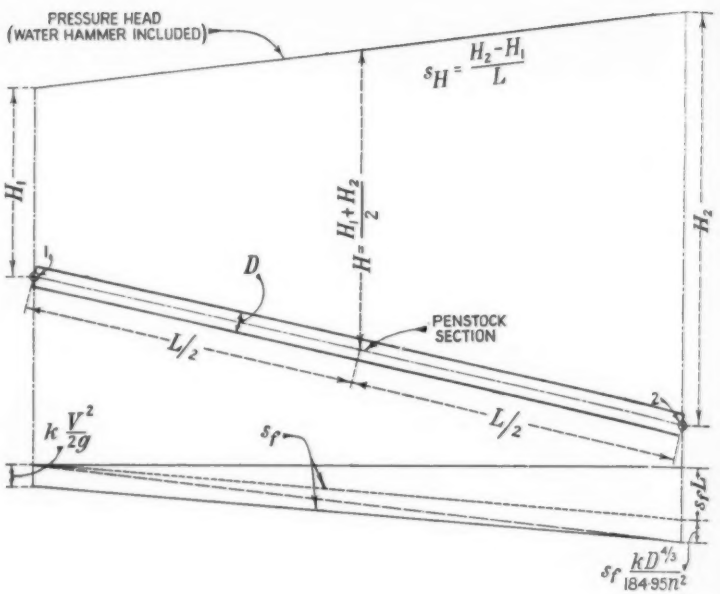


Fig. 1. Pressure head and distribution of local losses as equivalent friction loss

TABLE I

D feet	D^2	$D^{4/3}$	$D^{5\frac{1}{3}}$	$D^{7\frac{1}{3}}$
5·0	25·00	8·55	5,343·7	133,592
5·25	27·5625	9·12	6,931·9	191,059
5·5	30·25	9·71	8,883·8	268,736
5·75	33·0625	10·30	11,260·6	372,305
6·0	36·00	10·90	14,129·9	508,676
6·25	39·0625	11·51	17,566·8	686,208
6·5	42·25	12·13	21,654·3	914,893
6·75	45·5625	12·76	26,482·2	1,206,593
7·0	49·00	13·39	32,150·6	1,575,376
7·25	52·5625	14·03	38,767·6	2,037,723
7·5	56·25	14·68	46,450·8	2,612,859
7·75	60·0625	15·34	55,327·7	3,323,118
8·0	64·00	16·00	65,536·0	4,194,304
8·25	68·0625	16·67	77,224·3	5,256,082
8·5	72·25	17·35	90,552·6	6,542,424
8·75	76·5625	18·03	105,692·2	8,092,062
9·0	81·00	18·72	122,826·8	9,948,974
9·25	85·5625	19·42	142,152·9	12,162,959
9·5	90·25	20·12	163,880·3	14,790,196
9·75	95·0625	20·83	188,230·9	17,893,711
10·0	100·00	21·54	215,443·4	21,544,345
10·25	105·0625	22·27	245,769·1	25,821,119
10·5	110·25	22·99	279,474·9	30,812,109
10·75	115·5625	23·73	316,843·8	36,615,261
11·0	121·00	24·46	358,174·1	43,339,061
11·25	126·5625	25·21	403,781·8	51,103,636
11·5	132·25	25·96	453,999·2	60,041,390
11·75	138·0625	26·71	509,176·8	70,298,221
12·0	144·00	27·47	569,683·0	82,034,356
12·25	150·0625	28·24	635,905·3	95,425,538
12·5	156·25	29·01	708,250·2	110,664,101
12·75	162·5625	29·79	787,144·4	127,960,153
13·0	169·00	30·57	873,034·4	147,542,808
13·25	175·5625	31·35	966,387·6	169,661,420
13·5	182·25	32·14	1,067,693·9	194,587,207
13·75	189·0625	32·94	1,177,464·2	222,614,321
14·0	196·00	33·74	1,296,233·1	254,061,679
14·25	203·0625	34·55	1,424,555·4	289,273,549
14·5	210·25	35·36	1,563,013·2	328,623,527
14·7	217·5625	36·17	1,712,211·5	372,513,016
15·0	225·00	36·99	1,872,779·7	421,375,441

crements, Δt, the lengths, ΔL of these sections are also constant:

$$\Delta L = 0{\cdot}384 \frac{S}{D} \frac{E}{s_u} \Delta t \quad \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

The combination of the trial method (Eq. 2) with predetermination of the first trial value by Eq. 5 and employing Eq. 5b for the other penstock sections considerably reduces the amount of computations necessary to determine the most economic penstock size.

Further, the establishment of the variation of the shell thickness and of the section lengths of uniform thicknesses by Eqs. 6, 7 and 9 is greatly simplified.

Problems of the Waikato

FROM OUR NEW ZEALAND CORRESPONDENT

At the present time in New Zealand four hydro-electric stations are being built simultaneously on one North Island river—the Waikato. These are Whakamaru, Atiamuri, Waipapa and Ohakuri. This eventual aggregate output will be in the vicinity of 300 MW, which is approximately a quarter of the total power contemplated under the ten-station development plan for the river.

A source of so much of the North Island's power, the Waikato has always produced some problem at each of the hydro stations built on it. Each scheme to date has produced at least one major foundation problem, but a solution has been found in each case. Arapuni was distinguished by having a rock cliff which tilted; Karapiro, although apparently securely based on grey-wacke, had a concealed fault line running through it. At Maraetai the rock was strong but cracked: when the diversion cut was driven 14½ million gallons of water a day poured out. To prevent this, some 13,000 tons of cement were pumped into the rock. Whakamaru, also, was noted for its deeply cracked foundations which provided the greatest problem yet. Atiamuri's idiosyncrasy was water seepage caused by an older channel of the river which was much wider and deeper than the present channel. Following the example of the other projects, Waipapa has coyly revealed a 20 ft. layer of soft silt overlying the rock bridge on which the dam is to be built.

After so many years of dealing with the Waikato's tricks, the Ministry of Works engineers are more intrigued than worried about Waipapa's silt. They have proved they can find a way to overcome almost everything and are glad that the silt layer has been discovered in time to tackle it with modifications or new methods. The selfsame engineers wonder wryly what Ohakuri will produce.

Whakamaru. Whakamaru is all but finished, and the M.O.W. started filling the lake. The labour force is worked night and day to get half of the 100 MW power station in operation before the winter. The M.O.W. recently handed over the structure to the State Hydro-Electric Department.

Atiamuri. The M.O.W. are currently working on diversion structures and expect to divert the river early this year. Underground seepage along an old bed of the Waikato which is both wider and deeper than the present channel is the major headache here. The old river bed, which is situated under the water table, will be cut off by a membrane of concrete 5 ft. thick 50 ft. deep and 800 ft. long.

Waipapa. It was always known that Waipapa would be a problem site although the formation was thought good enough for the low earth dam which is to be built there, but, as always, the country held something back—this time a layer of soft silt 20 ft. thick. The silt is similar to quicksand or custard, pale purple when wet, off-white when dry. The silt is so thin that standard methods of drilling and sampling did not bring it to the surface in early investigations. Only recent improvements in technique have revealed it lying hidden below the sand of the still-flowing river. A strenuous programme of investigation work into the foundations for this earth dam is still being carried out by M.O.W. engineers.

The M.O.W. have also started to excavate the diversion channel, and, in all on the project, a total of one million yards of rock and alluvial material will have to be moved. The concrete diversion channel and spillway will be on the left bank of the river, the power house on the right.

Ohakuri. Ohakuri, the latest station in the line, is designed to produce 84 MW. It is planned to be finished for the winter of 1961. It will be the seventh hydro-electric station to be built on the Waikato. Because the present programme of works is beyond the capacity of the M.O.W. labour force of 1,200 workers, it is expected that a considerable part of this project will be carried out by private contractors. Tenders were called last month for the construction of the diversion tunnel. This tunnel will be 1,400 ft. long and 25 ft. in diameter.

AEG Hydro-Electric Generators. We have often had reason to be impressed by the excellence of production of brochures published by manufacturing concerns, but in our experience a new brochure under the above title published by Allgemeine Elektricitäts-Gesellschaft stands in a class by itself. In order to demonstrate the constructional features of AEG hydro-electric generators two machines are taken for detailed examination—a 50 MVA 500 r.p.m. 10·25 kV horizontal-shaft generator, and a 45 MVA 187·5 r.p.m. 13·8 kV vertical-shaft generator. Each machine is illustrated by means of a series of coloured sectional perspective drawings printed on transparent sheets and so bound together that as we turn the sheets the construction of the machine is gradually unfolded before our eyes in complete detail. Each machine is arranged on six transparencies, each printed on both sides. Quite apart from the excellence of the conception and of the quality of draughtsmanship involved, the perfection of the registration, both in printing and in binding, is a triumph of the printer's art. These transparencies are preceded by a lucidly written text, which, in the copy in our possession, is in perfect English.

Fig. 7. The underground machine hall at Storfinnforsen

The New Stations of the Krångede Power Company

Further to our recent series on the developments in the Ångerman catchment sponsored by the Swedish State Power Board*, we now give an account of the work of the Krångede Power Company in this area and describe the recently completed Storfinnforsen station and the Ramsele station now under construction

PART TWO

THE turbines are of the Francis type and were built by Nydqvist & Holm A.B., Tröllhattan. A cross section through one machine is given in Fig. 8, and various constructional views appear in Figs. 9 to 12. Each turbine is rated to give 47,000 h.p. under a net head of 48·5 m. at 150 r.p.m., the corresponding water flow being 80 cu. m. per sec.

The runners (Fig. 9) are of cast steel, the blades, of which there are 16, being integral with band and hub. A stainless-steel coating is welded to those portions of the blades where cavitation might occur.

The spiral casings (Fig. 10) have an inlet diameter of 4,830 mm., and are built of electrically welded steel-plate segments ranging in thickness from 12 to 25 mm. Each segment is riveted to the stayring, which is of cast steel.

Twenty guide vanes (Fig. 11) are provided, made of cast steel and integral with their trunnions. When the turbine is shut down, leakage between blades is minimised by a rubber strip inserted in the side of each vane at the point where the tip of the succeeding vane presses. Leakage between the blades and the main cover is arrested by a movable ring which is forced against the upper end of the vanes by water pressure. The turbine-shaft gland consists of three carbon rings held against the shaft by garter springs. It is claimed

* "Developments in the Angerman Catchment." WATER POWER, June, July and August 1955, pp. 202, 247 and 292.

that the mean value of the leakage is only 0·05 per cent. of the flow for which the turbines are designed.

An ejector serves to drain the turbine cover under normal service conditions, and any excess leakage is automatically handled by a float-operated d.c. motor-driven pump.

The turbine shaft bearing is lubricated by an Imo pump, geared to the turbine shaft, which raises the oil from a lower to an upper stationary container surrounding the shaft. A standby pump, driven by a d.c. motor, is available for emergency and for starting up.

The regulating ring is of cast steel and is mounted on roller bearings. Connection to the guide-vane arms is made by breaking links, which are fitted with electrical contacts to give an alarm in the event of link breakage. The servomotor (Fig. 12) is situated on a floor 3·5 m. above the turbine centreline, and operates the regulating ring through a vertical shaft.

Oil for the governor and servomotor is held in the usual air-cushioned storage cylinder at 20 kg. per sq. cm., and under normal conditions the pressure is maintained by an Imo pump gear driven from the turbine shaft, but for wide control movements and for emergencies, a pump driven by a 45 h.p. d.c. motor

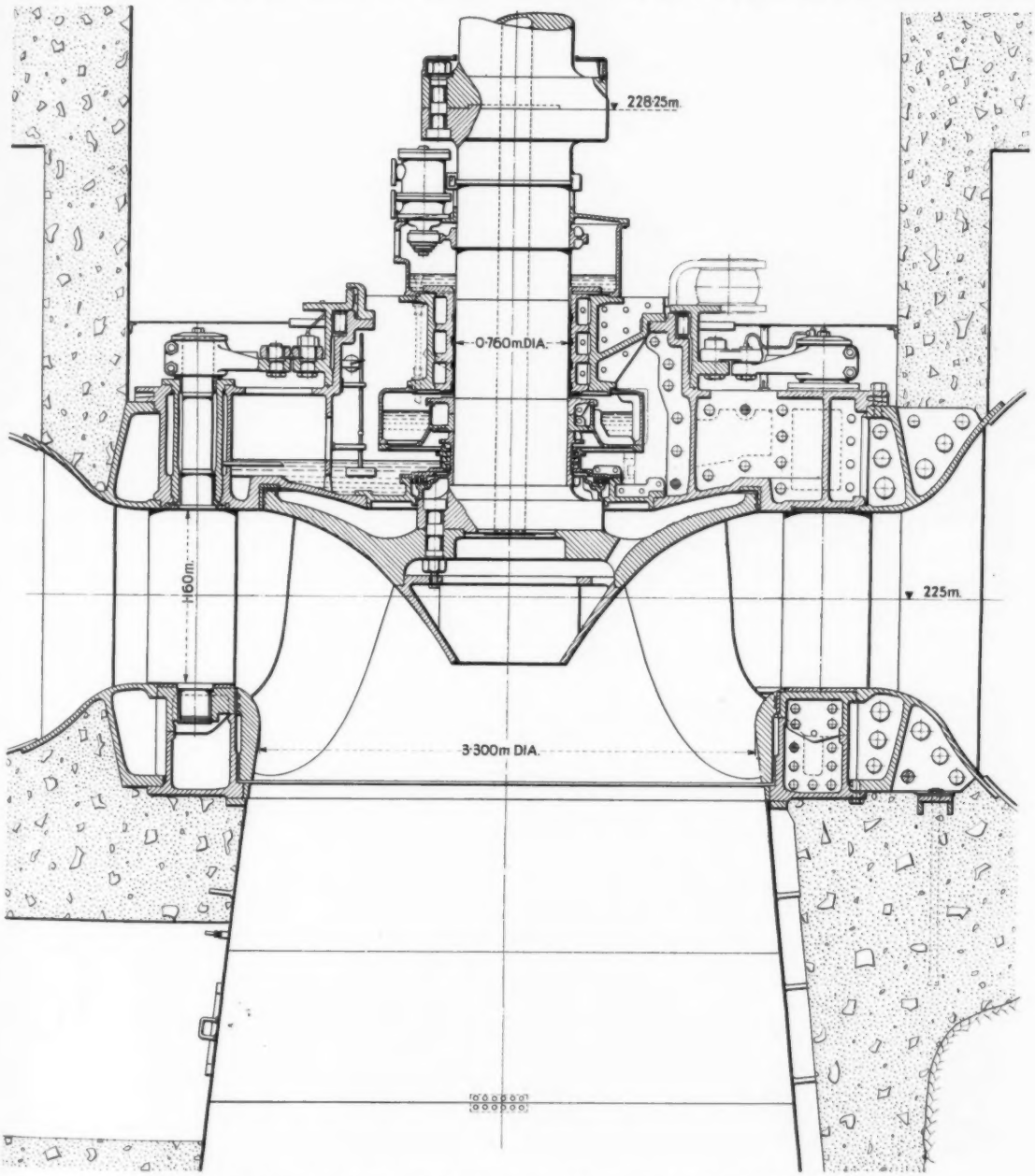


Fig. 8. Section through one of the 47,000 h.p., 150 r.p.m., 48·5 m. head NOHAB turbines

automatically cuts in to supplement the supply.

Governing is of the ASEA/NOHAB electro-hydraulic type described in our October 1952 issue, page 396. During our visit to the station we heard very favourable comments as to the quality of the governing.

Fig. 13 is of interest as it compares the guaranteed efficiency curve with that actually obtained on site during official tests carried out on one of the turbines. It will be seen that the guaranteed efficiency was well exceeded and that a maximum efficiency of 93·1 per cent. was achieved.

Alternators

The alternators were supplied by ASEA, and each is rated at 40,000 kVA at 0·9 power factor, the generating voltage being 18 kV. The flywheel effect is 1,275 ton-metre^2, the designed runaway speed being 290 r.p.m.

The thrust bearing is above the generator, this arrangement being preferred by the Krångede Power Company on account of the accessibility thus afforded. It is of the spring-supported pad type and incorporates a guide bearing consisting of pivoted pads bearing on the periphery of the thrust collar. Ducts cut in the thrust collar serve as a centrifugal pump to circulate oil across the bearing surfaces to an external cooler. The total load on the thrust bearing is 400 tons.

The lower guide bearing is also of the pivoted-pad type and is self lubricating.

Ventilating fans are mounted on both the top and the bottom rims of the rotor, and in summer the machines are ventilated on closed circuit, eight coolers being provided. In winter, external air is drawn in through an oil-film-type filter by a fan in a house on the surface, the warmed air from the generators being used to heat the station. The speed of the fan can be regulated by pushbuttons. CO_2 fire-protection equipment is available for each generator and its busbar shaft (to be described in a moment).

The stator windings are of the diamond type, consisting of a single conductor per coil, giving two bars per slot. Mica-tape insulation has been employed throughout, vacuum impregnated with a bituminous compound.

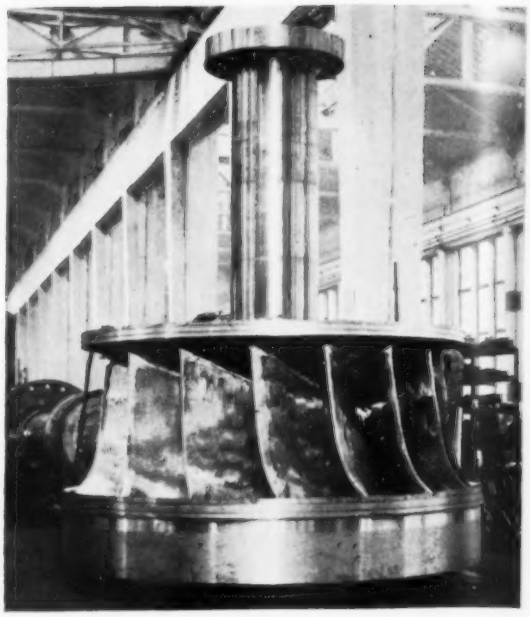


Fig. 9. One of the cast-steel turbine runners

Excitation is on the ASEA transductor system, the main exciters being mounted above the main generators, and the pilot motor-exciter sets on the machine-hall floor opposite their respective machines.

The generators have an efficiency of 97·4 per cent.

Other Electrical Equipment

The main circuit diagram is given in Fig. 15.

From each generator the busbars are taken up through a shaft (see Fig. 6) to a two-storey chamber just below ground level. In the lower storey are housed the generator voltage transformers and the compressors for the 18 kV air-blast switchgear. Two compressors are available, delivering air at 26-30 kg. per sq. cm., which is reduced to 14 kg. per sq. cm. for the 18 kV circuit breakers and to 10 kg. per sq. cm. for the 3 kV breakers. All these circuit breakers are located in the upper storey, together with the 18 kV current transformers.

The 3 kV system is for local and station supplies, and the 3 kV busbars are supplied via current-limiting reactors from the 18 kV bars through two 1,500 kVA transformers. Low-voltage station supply is stepped down from the 3 kV bars to 400 V.

A reserve supply is brought in at 40 kV from a private station, Graningeverken, owned by a pulp company. It is received by a 1,500 kVA three-winding transformer

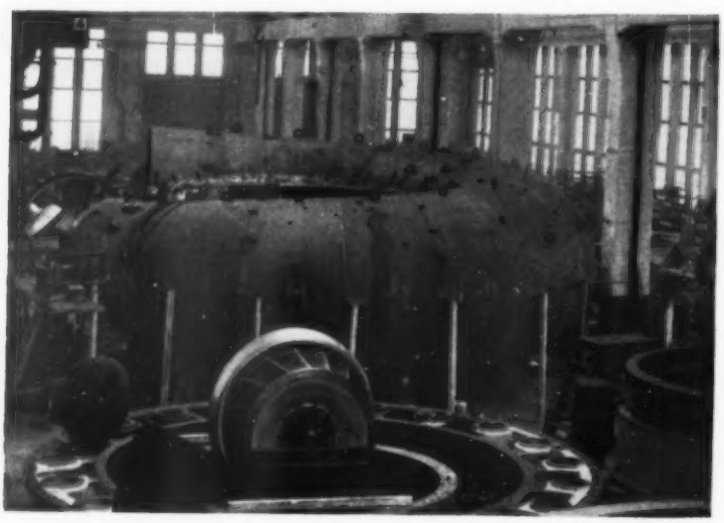


Fig. 10. Spiral casing of one of the turbines in the works

which links up with both the 18 kV and 3 kV busbars.

Direct current for control circuits and standby auxiliaries is normally supplied by duplicate 145 kW 220 V motor-generator sets, but a 608 Ah battery floats on the system to act as a reserve. For telephones and alarm circuits a 24 V 64 Ah battery is installed, charged by a metal rectifier.

To supply vital lighting points in the event of a total failure of the a.c. supply a d.c./a.c. motor-generator set has been installed, supplied from the battery. This is justifiable because the greater economy of fluorescent lights when operating on alternating current is equivalent to doubling the endurance of the battery.

By arrangement with the Swedish State Power Board the main output from Storfinnforsen is transmitted to the consumers through the 380 kV trunk line system of Sweden. The power is therefore stepped up from the 18 kV busbars through a transformer group consisting of three ASEA 48·5 MVA single-phase units, a fourth unit being available as a spare. These units are mounted in concrete cubicles, and stand over macadam-filled sumps large enough to contain the transformer oil in the event of a transformer explosion. Automatic fire protection is afforded by a sprinkler system supplied by Mather & Platt Limited, Manchester, England.

From these transformers the high-voltage conductors are taken to an adjacent outdoor substation. This is arranged on the double-busbar system, and four 380 kV air-blast circuit breakers are in service, three being of ASEA manufacture and one by Brown Boveri.

The control room contains an ASEA control desk, control board, and meter board. In view of the arrangement with the Swedish State Power Board for the use of the 380 kV trunk line, recording meters have been installed which summate the units delivered on the 18 kV and 380 kV systems. Carrier-current telephones communicate with other power stations and with the Company's head office in Stockholm.

Below the control room is a room housing the d.c. and a.c. local supply switchboard and the protective gear, which is of ASEA manufacture, except for the distance protection for the 380 kV lines, which are supplied by Brown Boveri.

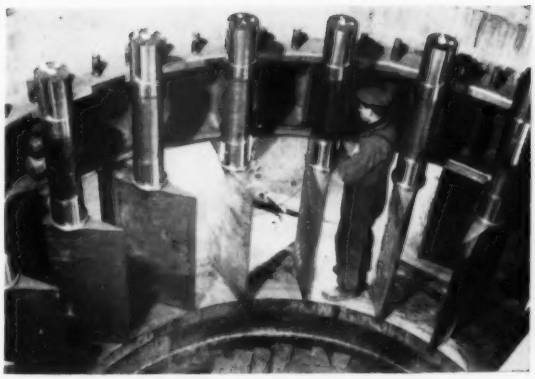


Fig. 11. Fitting the guide vanes

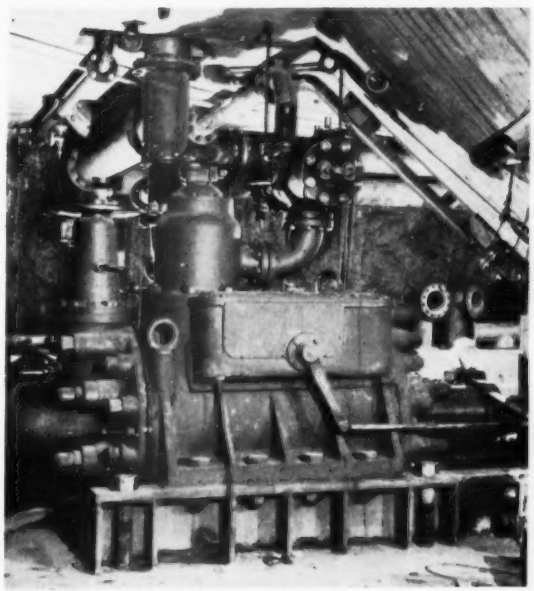


Fig. 12. One of the servomotor installations

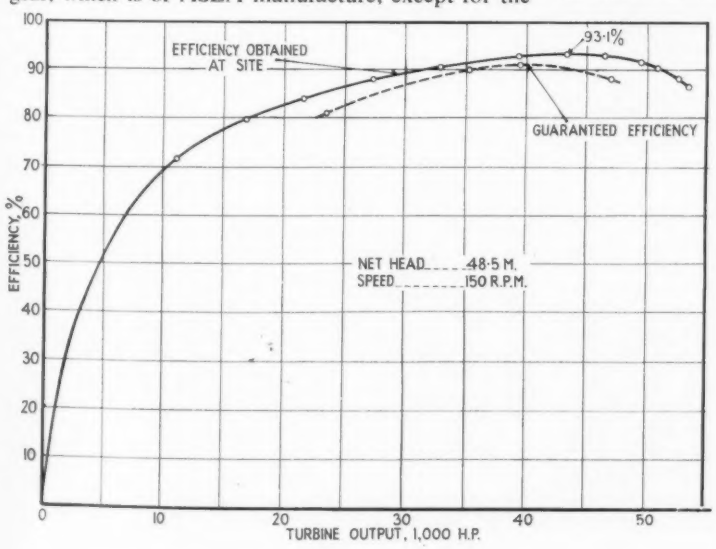


Fig. 13. Site test efficiency curve compared with guaranteed curve

Ramsele Station

Ramsele station, 11 km. downstream from Storfinnforsen, is still under construction, and when we visited the site was in process of excavation. From the general plan given in Fig. 16, it will be seen that the layout follows the same general scheme as that of Storfinnforsen, although naturally there are important differences of detail. The station will operate on a head of

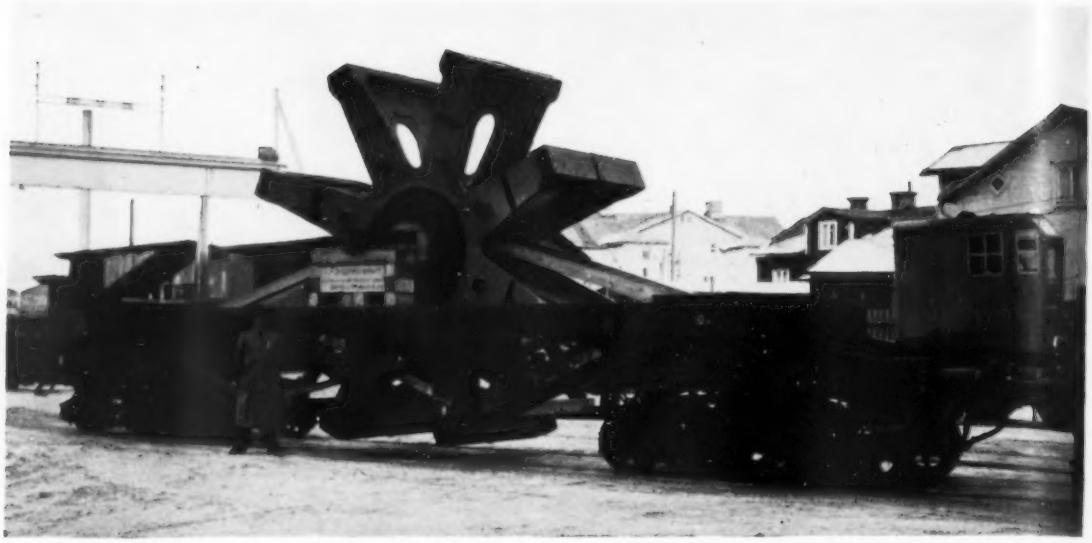


Fig. 14. Rotor spider of one of the 40 MVA ASEA generators leaving the works

79 m., and its reservoir level will correspond with that of the Storfinnforsen tailwater. It will contain three 50 MW sets comprising KMW turbines and ASEA generators, and each set will require a flow of 80 cu. m. per sec. at full load. The station will be connected into the 380 kV line between Storfinnforsen and Kilforsen, which passes close to the site.

The dam, like that at Storfinnforsen, will be of the plate buttress type, but will have no earthfill section. It will be about 37 m. high to lowest foundation and about 450 m. long, and will require about 70,000 cu. m. of concrete. The intake structure will be towards the right bank, to the left of it will be the log flume, and to the left again the spillway section, controlled by two tainter gates and one sector gate. A ground sluice will be incorporated in a block over the original river bed.

The construction schedule has been drawn up to suit the logging requirements of the upstream timber proprietors, and provides for cofferdamming the right-hand, left-hand, and centre of the river bed in three successive concreting seasons.

Cement is being procured from Limhamn near Malmö,and is brought by rail to Ulriksfors where it is pumped into a silo. Thence it is brought by covered lorries to the cement store, whence it is pumped as required to the concrete station. Aggregate is derived partly from a glacial deposit and partly from crushed rock spoil from the excavations. Natural shingle and sand are available from local glacial beds.

One of the main differences on the civil-engineering side from Storfinnforsen is the length of the tailrace tunnel, which is 7 km. long and is therefore not of the free-flow variety, there being a surge chamber section immediately downstream of the station. This tunnel has a normal section of 160 sq. m.—12 m. wide and 14·6 m. high, with a semi-circular roof—and is being driven from the power-station end and from two adits, one about halfway along the tunnel and 550 m. long, and the other near the outlet and about 750 m. long. The tunnel is being taken out in two sections,an upper section 10·6 m. high followed by a floor ripping of 4 m. Atlas Diesel light drilling equipment is employed, which for the upper section is mounted on a four-decked jumbo carrying 13 drillers. Half-second delay detonators are being used for this section and millisecond blasting for the floor ripping. Mucking is accomplished by a 2½ cu. yard North West excavator on each face delivering to a fleet of 13½ ton Euclid trucks.

An access tunnel, 5·5 m. wide by 7·5 m. high, has been driven at a gradient of 1 in 7 to the power station, and at the time of our visit drifts had been

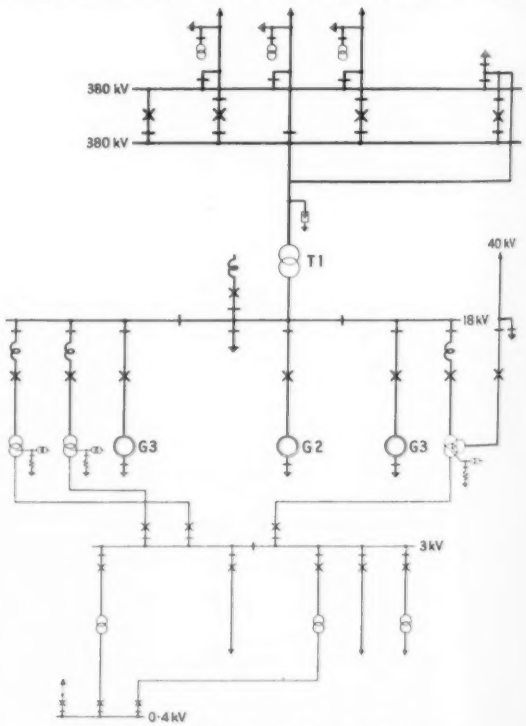


Fig. 15. Storfinnforsen main circuit diagram

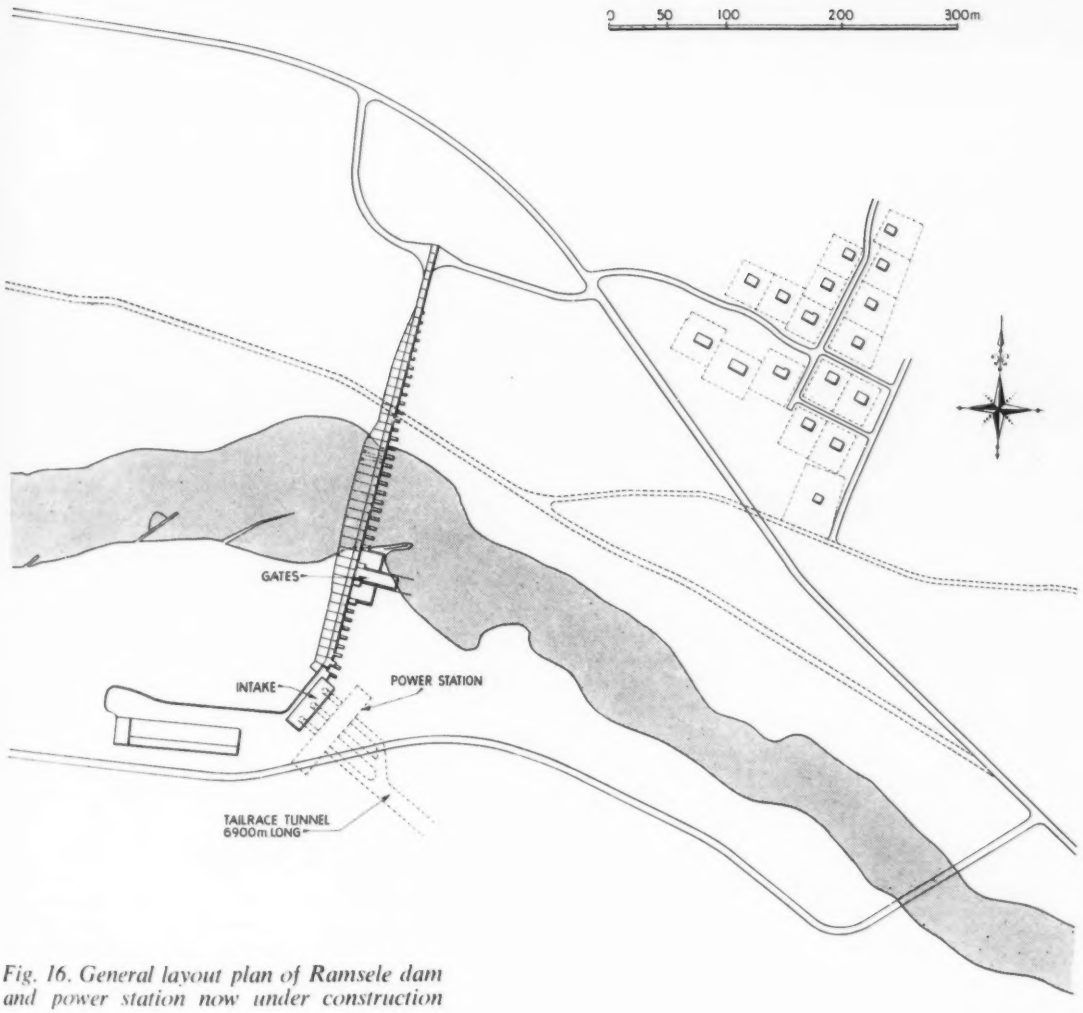


Fig. 16. General layout plan of Ramsele dam and power station now under construction

cut to the tailrace tunnel, surge chamber, and the roof of the machine hall.

At the sides of the river about 10 km. of road has had to be diverted, two bridges have been constructed for motor traffic, one of the suspension type to carry loads of 60 tons. There is also a temporary suspension bridge for pedestrians and a 15 ton construction bridge.

A 1,200 kW construction station has been built as a reserve for the main supply from Storfinnforsen.

Consulting Engineers and Contractors

The consulting engineers for Storfinnforsen and Ramsele station are Vattenbyggnodsbyräm, (VBB), Stockholm, who also designed the dams and the intake and sluice gates. The civil-engineering work was carried out by the Krångede Power Company. The following is a list of the main contractors concerned:

SLUICE GATES AND INTAKE GATES: AB Landsverk, AB Hammarbyverken.

TURBINES: *Storfinnforsen*, Nydqvist & Holm AB (Nohab); *Ramsele*, Karlstads Mekaniska Werkstad AB (KMW).

GENERATORS, TRANSFORMERS, CIRCUIT BREAKERS FOR 3, 18, 40 AND 380 KV, CONTROL-ROOM AND METERING EQUIPMENT AND PROTECTIVE GEAR: Allmänna Svenska Elektriska Aktiebolaget (ASEA).

DISTANCE PROTECTION AND 380 KV CIRCUIT BREAKER: Brown Boveri.

CRANES: Malcus Holmquist AB (MALCUS).

Acknowledgments

We gratefully acknowledge our indebtedness to Mr. A. Ohman, Chief Engineer of the Krångede Power Company, for the facilities he so kindly afforded us to visit the Fax river developments and to publish this article, and for the information and illustrations he placed at our disposal. At the site we were deeply appreciative of the courtesy extended to us by Mr. A. Almgren, the Resident Engineer, and our thanks are also due to his assistant, Mr. L. Hemming, the civil engineer who conducted us round the Ramsele workings. We also received valuable information from Nydqvist & Holm AB, and from ASEA.

Book Reviews

Engineering Fluid Mechanics. By Charles Jaeger. Translated from the German by P. O. Wolf. Blackie & Son Limited, 16/18 William IV Street, London, W.C.2, and 17 Stanhope Street, Glasgow, C.4. 1956. XVIII and 529 pp., 320 ff. Price 60s. net.

This is the third review of Dr. Jaeger's book to appear in WATER POWER* and indicates the importance we attach to the work. Dr. Jaeger's eminence in the field of hydro-electric engineering is unquestioned, and his power to keep abreast of new developments in the subjects covered by this book is proved by the successive additions that have been incorporated in the French and English editions, as well as his continued original contributions to engineering journals. With its numerous references to other recent works the book—effectively a third edition—is an up-to-date guide to the theory of engineering hydraulics and applied fluid mechanics as required by the engineer concerned with the overall design of water-power and associated projects, and particularly the civil-engineering designer of hydraulic details.

As in the previous editions, the subject is divided into five main parts: The physical basis of hydraulics, steady flow, unsteady flow, ground-water flow, and a group of appendices.

The first part briefly touches on the physical properties of water, on the theory of dimensions and of similarity, and on turbulence, and deals more fully with friction losses in pipes and open channels. It sets a standard in that the reader is credited with a knowledge of mathematics and elementary fluid mechanics corresponding to the syllabus of an engineering degree course of twenty years ago.

The second part contains a chapter on the basic hydrodynamic equations, which provides a transition from the fundamentals of the first part to the more immediately applicable content of the remainder of the book. Flow in open channels as a function of discharge, energy and momentum is discussed in the next chapter, which is followed by a treatment of gradually varied and discontinuous flow in open channels—subjects which cover much of the author's original researches. The discussion of back-water and draw-down curves, hydraulic jumps, flow through channels of varying cross-section and of varying slope, over weirs and past bridge piers, over side weirs and into side spillway channels is of immediate practical importance. A section on high-velocity flow has been added to this edition, and will be of especial interest to engineers dealing with the control of large discharges at high speeds.

The third part, on unsteady flow, deals with mass oscillations in surge systems, with water hammer, and with surges in open channels. This part—further extended since the publication of the earlier editions—is the longest of the book and includes the fruits of some of Dr. Jaeger's most important original studies. It covers analytical, numerical and graphical methods of computation of simple and multiple systems, with special emphasis on stability and governor characteristics. In view of the increasing number of underground power stations, the section on this subject will be of especial interest to many engineers.

The fourth part covers its subject so far as the theory of ground-water flow may be treated as an extension of the general theory of flow in open channels and in closed conduits. It will be found, however, that it deals with most of the problems likely to be encountered in the design of reservoirs.

The first appendix gives empirical values of coefficients required in head-loss formulae, and of meter and valve coefficients. The second appendix, though brief, deals with the flow of rivers in erodible material. This subject, often referred to as fluvial hydraulics, is likely to become increasingly important as hydro-electric development is more closely associated with overall river control. The third appendix, on density currents such as silt-laden underflow, will also be of interest to the designers of reservoirs on silt-laden rivers.

The footnotes have always been an outstanding feature of Dr. Jaeger's work as they refer the reader to papers and books specialising in the subject of a chapter, a section, or even a paragraph in the book, and they emphasise, in historical and biographical notes, that we have come far in the company of many fine scientists and engineers, and that ours is the task of contributing to further progress. Numerous additional references appear in the English edition, both to bring up to date the earlier footnotes and to include more important works in British and American literature.

In Mr. Wolf, Lecturer in Hydraulics at Imperial College, London, Dr. Jaeger has found more than a translator; he has found a collaborator who appreciates the significance of his work and who has done it full justice in preparing the English text.

Die Rechtsquellen des Internationalen Wassernutzungsrechts (The Law Sources of International Water Rights), by Dr. F. I. Berber, Professor of Law, Munich University. Published by R. Oldenbourg Verlag GMBH, 145 Rosenheimerstrasse, Munich, 1955. 206 pp. Price in Germany, DM.17·50.

In setting forth the problem and doctrine of International Water Rights in the two initial chapters, the author deals with the sources of International Law in its general aspects and the meaning of the term "Customary Rights." The various International Water Treaties in force between neighbouring countries in all parts of the world, as well as the nature of their law sources, are then briefly analysed. Austria, for instance, has water agreements with her six neighbours, water rights being established either by bilateral treaties or by the St.-Germain Treaty concluded after World War I; in the case of Great Britain, colonial territories only are involved and the treaties in force have been concluded with the powers controlling adjacent colonies. A separate paragraph is devoted to multilateral agreements, such as the 1921 Barcelona Convention on International Navigable Waterways, the General Convention on Hydro-electric Developments affecting more than one state, signed in Geneva 1922, and the Declaration of the Seventh International Conference of American States held in December 1933. The nature of the Law Sources of International Water Treaties is analysed in Chapter 5, and Chapter 6 briefly discusses the application of decisions taken

* The original German edition was reviewed in WATER POWER January-February, 1950, p. 41, and the French edition in January, 1954, p. 27.

by International Tribunals or other International Organisations with a view to discovering possible law sources. The bearing on International Water Rights of law sources derived from internal legislation is examined in Chapter 7, and Chapter 8 assesses the value of general principles of law as law sources of International Water Rights. The volume concludes with a review of the future prospects of international legislation on the development and utilisation of water resources. An extensive index is appended. Dr. Berber's work is a most interesting contribution to the study of the legal aspects of the multi-purpose development of international waterways and will prove of great value as a reference book on the subject.

Cavitation in Hydrodynamics. Published for the Department of Scientific and Industrial Research by H.M. Stationery Office, London. Price £1 10s. 0d. net (U.S.A. $5·40). By post, £1 11s. 8d.

This volume contains the proceedings of the First International Symposium on Cavitation in Hydrodynamics, which was held at the National Physical Laboratory, Teddington, on September 14-17, 1955. It contains the full texts of 22 papers that were presented and summaries of the discussions. Six sessions were held, under the following subjects: A critical review of recent progress in cavitation research; factors governing cavitation inception; experiment techniques; scale effect factors; effects on hydrodynamic performance; and cavitation damage. A record of an informal discussion on ultrasonic cavitation is also included.

Much of the work described has obviously been inspired by the requirements of marine engineering, but as all the papers deal with fundamental questions this volume cannot fail to be of the utmost value to designers of hydro-electric structures and plant, as it provides a digest of the latest investigations and conclusions on this vital subject of cavitation. The membership list, which numbers upwards of 130, includes recognised authorities from Great Britain, the major European countries, Russia, Canada, the United States, India and the Gold Coast.

La Construction des Tunnels, Galeries et Souterrains (Tunnelling Practice), by G. Bardout and P. Berny. Published by Eyrolles, 61 Boulevard Saint-Germain, Paris-V^{e}. 288 pp., 141 ff., 9 folding diagrams in appendix. Price, cloth bound, Fr.3,400.

As Engineer-in-Chief and Departmental Engineer of the Technical Services of the Paris Corporation, the two authors played a prominent part in the planning and construction of the city's underground railway. It is therefore quite logical that their work on tunnelling practice should be devoted almost entirely to railway tunnels. As they themselves remark, however, in their definition of a tunnel, their subject is closely connected with the practice encountered in hydraulic structures of the same kind, and they treat it with such authority that the work will be welcomed by the civil engineer specialising in water-power development. After all, whether tunnels are built for railway traffic or power-water supply, the construction procedure is the same and varies only with the nature of the strata and the topography of the land through which they are driven. There is therefore hardly any section of the book which cannot be applied to power tunnels or other underground galleries occurring in hydro-electric schemes. The illustrations, line and photographic alike, leave nothing to be desired, and the folded diagrams appended at the end of the volume are particularly excellent.

The British Civil Engineering Contracting Industry: Illustrated History. The Federation of Civil Engineering Contractors, Romney House, Tufton Street, Westminster, London, S.W.1. 200 pp., 275 photographs. Price £3 3s. 0d.

This book describes the vital role played by British civil engineering contractors in Britain's growth as an industrial power during the past 200 years. While of necessity much of the book is a backward glance at the industry's achievements, it is concerned also with the present—in the part being played by British civil-engineering contractors in the new field of atomic power. Reference is also made to their participation in development projects overseas, and photographs are included of the new harbour at Aden and the Owen Falls hydro-electric scheme.

The book is divided into five main chapters: Transport and Communications; Fuel and Power; Public Health; War; and Industry. Each of these chapters is further divided into subsidiary sections. Hence, Transport and Communications deals separately with canals, railways, docks and harbours, roads, airports, and communications. Fuel and Power is subdivided into sections on gasworks, power stations, hydro-electric schemes, coal, oil, and atomic power. Public Health deals in turn with water supply, drainage and sewerage, sea defences and recreation. The chapter dealing with the contracting industry during wartime shows its contributions not only in the defence of the civilian population in Britain with air-raid shelter construction, but also in the allied offensive in Europe through airfield construction, the building of the Mulberry harbour, and the reconstruction and maintenance of lines of communication in the liberated countries of Western Europe. Royal Ordnance factories, essential services and communications, fortifications and the Pluto pipeline are also dealt with in this chapter. The final chapter of the book, Industry, deals with industry in general, steel, agriculture—with mention of overseas irrigation schemes such as the Aswan dam—and atomic factories.

A preface to the book has been contributed by the President of the Federation, Sir George M. Burt, and an epilogue by Mr. Robin McAlpine, Chairman of the Council of the Federation for the year 1955-56.

Zur Hundertjahrfeier der EHT (Centenary of the Federal Technical University, Zurich). Published by Schweizerische Wasserwirtschaftsverband (Swiss Water Association), 10 St.-Petersstrasse, Zurich 11, as a special issue of "Wasser- und Energiewirtschaft" (No. 9-11, 1955). 8 in. by 11¼ in., 62 pp., 59 ff. Printed on art paper, bound in thin boards. Price in Switzerland, Sw. Fr. 7·6).

Most of the pages of this handsome publication are filled by a comprehensive study of "Water Intakes in Silt-Laden Rivers," contributed by Professor Dr. R. Müller, Head of the Hydraulic Division of the Testing Institute for Hydraulic and Earth Structures attached to the Swiss Federal University in Zurich. The first of the three main sections of the paper deals with the

primary conditions conducing to the correct planning and designing of a water intake in a silt-laden river. The nature of the river course on which an intake is to be set up varies with the ratio of silt inflow to silt outflow; accordingly, the author divides these courses into steady, alluvium, and erosion stretches. With regard to the latter, in which the transportation capacity is greater than the silt inflow, a distinction is made between courses characterised by a slow deepening of the channel and a loss of gradient, and courses submitted to latent erosion, in which coarser material sinking to the bottom consolidates the channel bed. If surveys taken over several decades establish that there has been no alteration of the stream bed or gradient in a particular course, we have to deal with the ideal case of a steady course. The choice of the most favourable intake site is discussed from the aspect of the extent and character of the silt load on the one hand, and of the pattern of the site itself—river bend or straight stretch. The deflecting action of bends, inlet and forebay, as well as intake weirs, is also reviewed, and a separate subsection is devoted to the investigation of the effect of tranquil and shooting flow on the intake section. Part II covers the important question of model tests carried out in connection with intakes set up in steady and latent-erosion courses; practically all cases occurring in actual practice are reviewed, and the description of the tests is accompanied by excellent photographs of the models. All these tests have been effected at the Federal Technical University under the direction of the author, who gives some prominence to the tests devoted to the Rhone intake of the Lavey plant, a large-scale structure erected on a typical latent-erosion course. Part III summarises the main factors to be taken into account when working out an intake project: installed discharge, character of the river course involved, discharge at which silt transport begins, and most favourable site. A section deals with the planning procedure to be followed, and separate paragraphs are devoted to inlets, weirs, and accessory structures. In his conclusions, the author emphasises the importance of careful planning when the setting up of intakes is contemplated, since these structures must ensure for many years dependable operation of the plants and installations involved. Particular stress is laid on model tests, especially in the case of steady courses carrying large discharges and submitted to operating restrictions. The last word on intakes, especially in connection with hydro-electric developments, has not been spoken, nor is any such claim made in this remarkable paper, but every credit must be given to Professor Dr. R. Müller for this outstanding contribution to the commemoration of the Centenary of the ETH.

Hydraulics Research Board Report

Most of the work of the Hydraulics Research Station of the Department of Scientific and Industrial Research is concerned with harbour, tidal, estuary and coast-erosion problems, and the important work carried out in this field during the past year is recorded in the Hydraulic Research Board's Report for 1955.* Certain investigations, however, are of direct hydro-electric interest, and of these the most important is that on a model of a tainter-gate intake for the Caroni development in Venezuela, which will have a bank of six intakes. The model is a geometrically similar reproduction of one intake from the trashrack to a point in the penstock about 5 m. above the level of the turbine, and is on a scale of 1:26·25. Experiments were carried out with the object of checking the general behaviour of the flow and the losses of head through the intake for the maximum working discharge over the full range of anticipated water surface levels; emergency closures of the tainter gate and the turbine guide vanes were simulated in the model both for the maximum working discharge and for the maximum discharge which might occur in the event of the load suddenly coming off and the turbines running away. Losses across the trashrack were found to agree well with calculations based on straightforward assumptions. The general behaviour was found to be good, the flow lines following the boundary with no eddying or separation. The upstream surge resulting from an emergency closure of the tainter gate reached a maximum of 1·74 m. (prototype) for the runaway discharge combined with the lowest anticipated water surface level.

In connection with the proposed Severn Barrage scheme, experiments on tidal reproduction in the Severn pilot model, the scales of which were 1/8500 horizontally and 1/200 vertically, were completed during the year. The model has now been remoulded to a vertical scale of 1/400, thus reducing the vertical exaggeration from 42·5 to 21·25, and experiments are in progress to examine the feasibility of reproducing the natural estuarine circulation. The bed material is silica sand with a mean grain diameter of 0·17 mm., and the tides are generated by means of the original plunger mechanism.

Basic research has been initiated on the effects of suspended load on turbulence and slope in a channel, and on the discharge characteristics of a drum weir.

Stage I of the Main Hall of the Research Station at Wallingford was handed over for use in January 1955, and has proved a great acquisition, but even so, the Board have had to refuse important investigations on account of lack of facilities. It is to be hoped that Stage II of the Main Hall will be authorised for construction as soon as possible.

* "Hydraulics Research, 1955." Department of Scientific and Industrial Research. H.M. Stationery Office. Price 4s. net.

British Brown-Boveri Jubilee

At a luncheon held in London recently to celebrate the fiftieth anniversary of the founding of British Brown-Boveri Limited, Mr. H. Oswald, the Managing Director, spoke of some of the technical developments with which his company had been concerned since its inception by Mr. A. C. Eborall. Steam turbo-generators and turbine-driven compressors and blowers formed a major part of the company's installations, but a useful bread-and-butter line was the exhaust-gas turbine-driven supercharger for diesel engines. On the electrical side the Brown-Boveri voltage regulator had won universal acceptance, and pioneer work had been done with steel-tank mercury rectifiers.

Gilbert Gilkes & Gordon Centenary

Fig. 1. Main turbine erection bay. The horizontal Francis turbine on the right is for Iceland and is fitted with a Giljet governor

IN various branches of engineering, centenaries seem to be becoming fashionable, and during the past year or two our pages have referred to such events on the part of several famous firms. Nevertheless, there is a particular pleasure in recording the centenary of a firm that has built up a unique reputation for the design and manufacture of smaller turbines. This is a field that has been somewhat neglected—doubtless for sound reasons—by many of the world's leading turbine builders, but Gilbert Gilkes & Gordon Ltd., Kendal, Westmorland, England, have always understood the problems and the potentialities of this kind of market, and have developed original designs to meet the special conditions involved.

Just one hundred years ago—on August 17, 1856—Williamson Brothers, the originators of the present firm, received an order for their first water turbine. It was a 5 h.p. "Vortex" machine for a nearby farm, and was designed by Professor James Thomson, the brother of Lord Kelvin. Professor Thomson's drawing of this turbine is still preserved in Gilbert Gilkes & Gordon's drawing office, and the turbine itself is still in working order and is used when required. Quite a number of these old turbines are still in operation, and during a recent visit to the district in connection with the centenary celebrations, we saw in operation a turbine built in 1876 and still running daily to drive a diamond saw and a lighting generator at a local slate works.

Fig. 2. Lowering the core into the mould for a turbine casing

Since these early beginnings Gilbert Gilkes & Gordon Ltd. have built turbines of all types and for all parts of the world, and in sizes ranging from a few horsepower to a 9,000 h.p. machine operating under a head of 2,600 ft. for the Bolivian Power Company in the Andes.

The domestic history of the firm is full of interest, but it seems to us that it will be of greater value to our readers to summarise the special contributions made by Gilbert Gilkes & Gordon Ltd. to the field of small and medium-sized turbine design.

An outstanding development in 1919 was the invention of the Turgo impulse wheel. This is a free-jet impulse turbine in which the jet enters the runner from one side at an angle and is discharged upon the opposite side. Its great advantage is that its specific speed is substantially higher than that of a Pelton wheel, and with the original design a ratio of 5·6 to 1 was obtained between the mean diameter of the runner and the diameter of the jet. At that time it was unusual to operate Pelton wheels with a ratio lower than 10 : 1. Subsequently further design improvements took place

until in 1936 a wheel was designed giving a high efficiency with the runner/jet ratio as low as 4·4 : 1 and a specific speed of about 11·5 r.p.m. (English units). The Turgo impulse wheel virtually eliminated the necessity for building multi-jet Pelton wheels, as its speed was even higher than that of a normal two-jet Pelton wheel, the turbine itself being smaller and very much simpler. For medium heads and outputs the Turgo impulse wheel proved to be an outstanding success and many hundreds are now operating in different parts of the world.

Another direction in which the firm has made a number of original contributions to design is in that of governing. Impetus has been given to these developments by the special requirements of the smaller turbine, because so many plants of this kind operate in isolation, i.e., not connected to an electrical network. Obviously the governing of a plant that is the sole producer of a local electricity supply must be extremely close. Further, many of these smaller plants are installed in remote situations, and the governor must be capable of simple adjustment by the local attendant and must not require to be set by a specialist mechanic, whose journey to site might be prohibitively expensive.

The first oil-pressure governor was built in 1907, and after the first world war the governors were completely redesigned, leaving the equipment basically as used today. For impulse turbines up to about 300 h.p. a shaft governor was also designed which is believed to be one of the most rapidly acting turbine governors in the world.

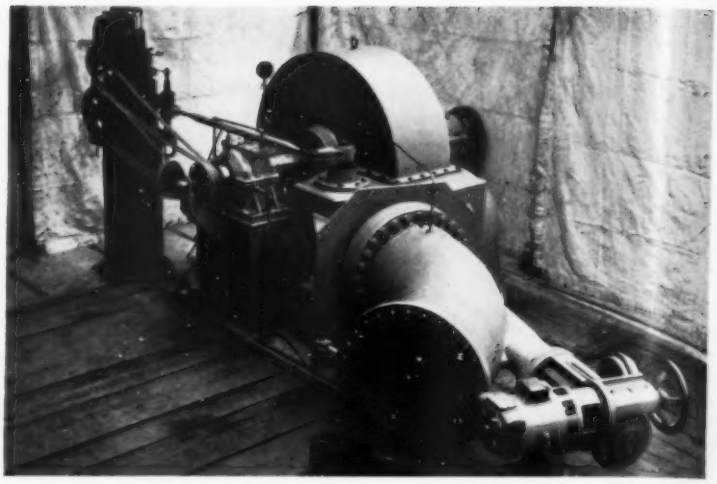


Fig. 3. 3,400 h.p. Turgo impulse wheel supplied to Otago Electric Power Board, New Zealand

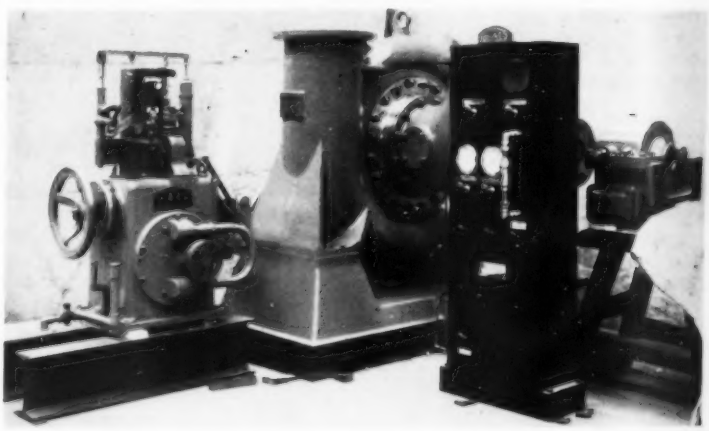


Fig. 4. 685 h.p. power-recovery Francis turbine supplied to Imperial Chemical Industries

Many smaller installations operate as run-of-river domestic units driving d.c. generators, or on compensation water, a fixed quantity of which must be passed through the turbine irrespective of the electrical load. In such cases it becomes economic to dispense with the mechanical governor, leaving the turbine on full discharge, and to incorporate the firm's electric brake governor, which was patented in 1925. This operates on the principle that if the load on the turbine be kept constant there will be no change in speed. An electric brake is therefore connected to the generator, and when load on the generator is reduced a complementary load is automatically imposed on the brake, the heating of the brake drum being dissipated by cooling water.

The most recent addition to the firm's special governing appliances is the Giljet hydraulic impulse brake.* This consists of a totally shrouded flywheel in the rim of which specially designed "buckets" are formed. On a rejection of load a reverse jet is caused to impinge on these buckets, rapidly building up a retarding torque corresponding to the amount of load rejected. The jet is then closed very slowly, giving the effect of a gradual reduction of load on the turbine. The system has been evolved for the governing of Francis turbines operating with very long penstocks where it is often impossible and always expensive to build a surge tower. It has proved remarkably successful and often enables great savings to be made in constructional work.

A special class of turbine with which Gilbert Gilkes & Gordon Ltd. have had much experience is for power recovery in chemical works. Certain chemical processes require water or other liquid to be pumped through an apparatus under high pressure, and the release of pressure as the liquid is discharged from the apparatus represents a waste of power. This can be largely recovered by passing the discharge through a

* This is fully described, and performance curves are given, in "Governing by Hydraulic Impulse Brake" by Paul N. Wilson, WATER POWER, January 1953, p. 14.

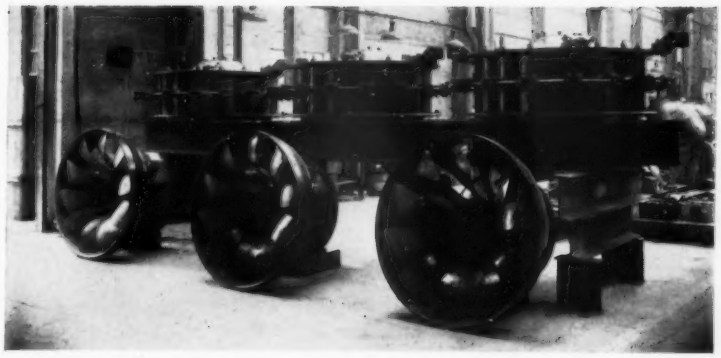
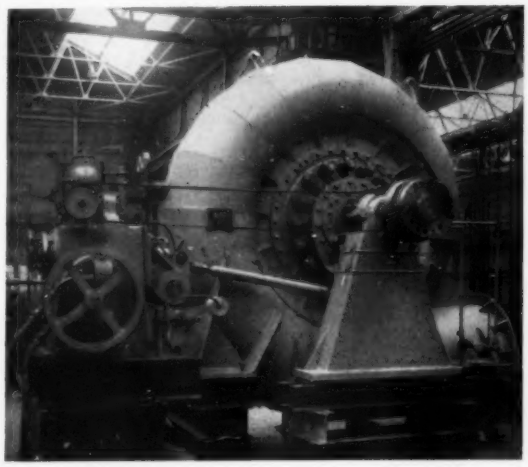


Fig. 5 (right). Three 204 h.p. open-type Francis turbines supplied for the Lhasa hydro-electric scheme, Tibet

Fig. 6 (below). 1,400 h.p. Francis turbine supplied to Taupo Town Board, New Zealand



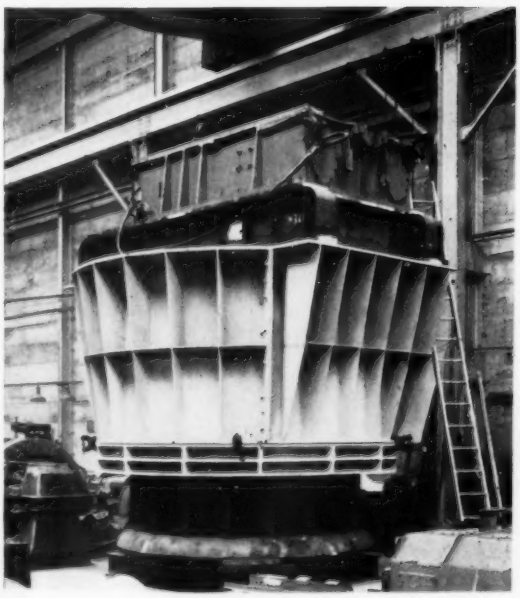


Fig. 7. 3,600 h.p. vertical-shaft Francis turbine for Mullardoch tunnel power station, Scotland

turbine, which may conveniently be coupled mechanically to the pump unit. Such an application presents serious problems in corrosion, but these have been mastered by correct design and selection of materials.

Another speciality, which has been in increasing demand during recent years, is in the field of instructional turbines for universities and technical colleges, and in specially designed laboratory units for fundamental research. These machines are made in Pelton, Turgo, Francis and Kaplan types.†

Quite a number of machines installed in remote mountain areas have presented an acute problem of design for transport. As long ago as 1906 four turbines were sent to the Caylloma Silver Mines, Peru, where they were installed at an altitude of 15,000 ft. in the Andes. These turbines and all the associated equipment had to be broken down for mule transport, and subsequently the firm supplied a number of turbines broken down to comply with rigid limits of weight and overall dimensions. Air transport has now largely done away with these very severe restrictions, but in 1951 and 1952 three 125 kW low-fall hydro-electric sets were shipped to Calcutta for onward transport to Tibet for providing light and power to the city of Lhasa. In this instance the maximum weight restriction was approximately one ton for transport over the Himalayan passes.

Our personal interest is naturally in turbines, but an important part of the firm's business is in the manufacture of GGG self-priming pumps. These pumps represent another original development and are used for marine-engine cooling, sump drainage, petrol pumping, crop-spraying and many other purposes.

Although the firm's works occupy the site originally leased by Williamson Brothers, they have been extended and entirely remodelled, and now form a modern and well-equipped establishment comprising drawing office, pattern shop, foundry, welding shop, machine and fitting shops, toolroom, packing and loading bay, demonstration room, and research and testing department. The water-turbine testing tank is stated to be the first permanent equipment to be built by any manufacturer in the United Kingdom.

We trust that when the issue of WATER POWER for August 2056 appears it will duly chronicle the bicentenary of this English Lake District firm. The present editor would like to hope that he will be able to attend the celebrations, but he has his doubts.

† For a full description see "Instructional and Experimental Water Turbines" by P. J. E. Stride, WATER POWER, October 1952, p. 388, and "Kaplan-type Instructional Turbine," WATER POWER, November 1954, p. 440.

Welding a Large Francis Runner

AN interesting example of welded construction is reported from Sweden, where a large Francis turbine runner was recently fabricated at the KMW works by a technique determined by laboratory and full-scale tests. The runner is 4·85 m. in diameter and weighs 35 tons, and was built up from separately cast parts, the band and blades being of 13% Cr stainless steel and the hub of carbon steel. Each blade weighs about 925 kg. The procedure was as follows:—

All stainless-steel parts to be welded were first "buttered" at the joining surfaces by a layer of austenitic weld metal. For this operation the parts were preheated to a carefully controlled temperature by induction heating at normal mains frequency, this stage in the case of the band being shown in Fig. 1 and in the case of a blade in Fig. 2. Thereafter the various parts were stress relieved in a specially built furnace.

Then the runner was built up (Fig. 3) the blades being set to jig and tack welded, after which the complete joints were welded without preheating (Fig. 4).

When the welding had been completed the entire runner was stress relieved in the furnace already referred to (Fig. 5). This furnace was wood fired, and the furnace was tested, and the staff trained by a series of preparatory exercises, to keep the correct temperatures and firing conditions.

The runner was then turned outside to its final dimensions (Fig. 6), and the welded joints were ground and polished, as also were all other waterways (Fig. 7). Then followed a minute checking of the welded joints using all available methods, including gamma rays. There were no cracks nor other defects in the welds.

Great advantages are claimed for this method of fabricating runners as compared with solid casting, of which the following may be mentioned:—

1. The separately cast blades are ground complete and ready and are given their correct shape before they are mounted in the runner.

2. Runner band and hub are turned in the waterways.

3. When the blades are set up for welding they are adjusted so

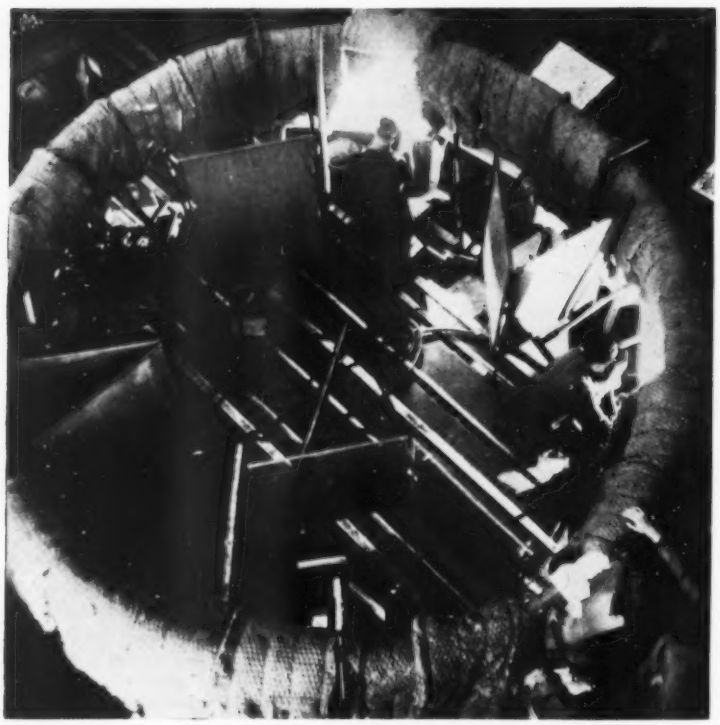


Fig. 1. Preheating and "buttering" the runner band

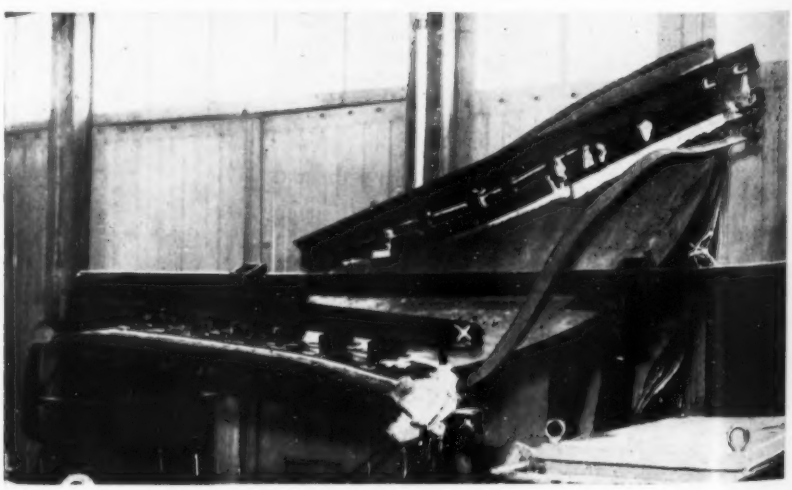


Fig. 2 Preheating one of the blades by induction

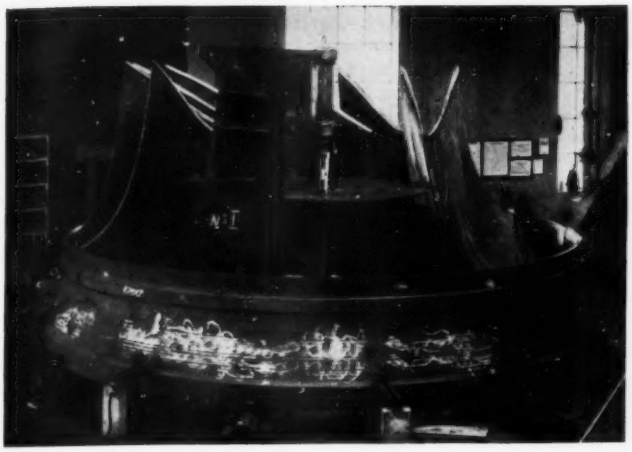


Fig. 3. Building up the runner

Fig. 4. Welding the runner

that the outlet openings of the runner are in close agreement with the drawing.

4. If there is any difference in the weight of individual blades they can be arranged in the runner so that practically perfect static balance is obtained.

5. Band and hub, when cast separately, can be given turned and concentric radiused surfaces and therefore cannot fail to be statically balanced.

The following firms have co-operated to achieve this successful result:—

The blades were cast and adjusted at Avesta Steel Works, their experts having also determined by experiments the welding method and composition of the electrodes to be used. Band and hub were cast at the Domnarvet Steel Works.

The ESAB people were consultants in connection with the induction heating and also supplied the requisite transformers.

The welding and finishing of the runner were performed by AB Karlstads Mekaniska Werkstad's (KMW) works at Kristinehamn, this company being contractors for the job as a whole.

The runner is a good example of the work of modern Swedish heavy industry and certain aspects of the method of manufacture can be considered unique.

Fig. 5. The stress-relieving furnace

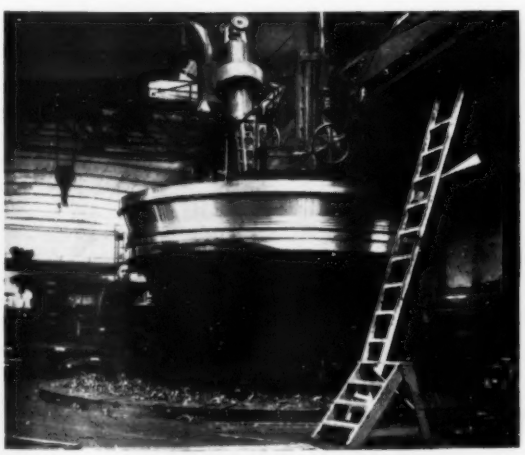


Fig. 6. Turning the runner on the mill

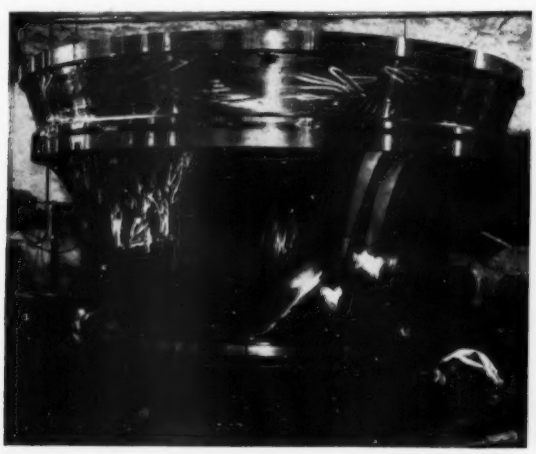


Fig. 7. Runner finally ground and polished

Abstracts from the World Technical Press

Mangla Dam Project

The dependable perennial supplies from the West Pakistan rivers are being utilised almost to the full, and any increase in crops depends upon the conservation of flood waters which now escape to the sea. Faced with this situation, Pakistan is now embarking upon a programme of storage reservoirs of which Mangla is the initial step. The dam, almost two miles in length at the crest (1,200 ft. above sea level), crosses the Jhelum River about two miles upstream of the Upper Jhelum Canal regulator, and has a maximum height from rock to crest of about 360 ft. The reservoir will reach an effective capacity of 3·5 million acre-ft. A power house sheltering four 75,000 kW units, operating at between 180 and 315 ft. head, will flank the dam on the left bank, and the spillway will be at the other end, the tailrace leading to the Upper Jhelum Canal. This spillway, fitted with automatic gates, will be designed for a routed flood of one million cusecs capacity. In addition to irrigation, power generation and flood control, the scheme is to include recreation facilities and fish culture, and will, moreover, bring about considerable improvements in communications. (Ch. Abdul Hamid, Editor, *Engineering News*, Lahore, Vol. 1, No. 1, February 1956, p. 13, 5 pp., 2 maps.)

A Novel Type of River Intake

The ideal river intake operating in conjunction with a hydro-electric power system should be designed so as to admit to the turbines a fully adequate supply of desilted water. In this paper, the author, Head of the Department of Hydraulics and Professor of General Hydraulics at the La Plata University, describes his new conception of a river intake, together with the tests which led to it. His aim was to arrive at a solution which would ensure a correct working of the intake under practically any foreseeable conditions, and it was only at the fifteenth attempt that he found the answer to his problem. To avoid too favourable operating conditions, the final 1/40 scale model was sited on a straight stretch of channel with gravity forces predominating and a highly turbulent flow. The model comprises a dam closing the straight stretch of the river and the intake structures proper, supply or diversion canal, an insubmersible guide wall, a sill notched at its downstream end, a flushing gate, an intake chamber (optional), and the intake sluice gates. The tests, effected with materials of various granulometric composition weighing 2·6 g. per cu. m. and differing in concentration between 0·5 and 1 per cent., were divided into three groups representing conditions occurring in actual practice: flood discharge, low-water level, and torrential flow. The main claim made for this novel type of intake, for which a patent has been taken out, are: a practically unlimited range of applications, extending from torrents to stream beds laden with sand and mud; its comparatively small size, which, combined with simplicity of design, reduces initial expenditure and maintenance costs; low operating costs due to an easy control, and a minimum of movable parts. (M. José S. Gandolfo, *La Houille Blanche*, Vol. 11, No. 1, January-February 1956, p. 53, 22 pp., 16 photos of models, 5 graphs, 2 tables. English Digest p. 7.)

NOTE: We draw attention to the "Pictorial Supplement" appended to the above mentioned issue of *La Houille Blanche*, which is devoted to the extensive works carried out in the Beni-Moussa plain, Morocco. In addition to large-scale irrigation installations, these works also include the Oued el Abid development with its two power plants, Bin-el-Ouidane and Afourer (p. 83, 12 pp., 30 ff.).

Air-Friction Losses in Pelton Wheels

A detailed account is given of the tests undertaken at the laboratory of the Federal Technical University, Zurich, with a view to arriving at a method which would enable air-friction losses in Pelton wheels to be determined to an adequate extent of accuracy. The tests were effected with models of enclosed and non-enclosed Pelton wheels, and the results obtained were supplemented by results of tests carried out on large wheels manufactured for hydro-electric plants. New formulae are given for non-enclosed solid and two-part Pelton wheels, from which air-friction losses can also be estimated for enclosed wheels by means of correction graphs. Tests were also made with wheels revolving in the opposite direction, and wheels moving in a water-cooled casing, and their results are analysed. The report ends with a description of the various measuring processes applied. It is claimed that the method of computation worked out in these tests for determining air-friction losses in Pelton wheels is a substantial improvement on the formula included in the ASME Power Test Code for Hydraulic Prime Movers 18-1949 (Chapter 54, p. 12), the only formula previously published. The author believes that the reliability of the new Swiss formulae could be increased if tests were carried out on large Pelton wheels, and their results made available. (Professor H. Gerber, Head of the Institute for Hydraulic Machines and Plants, Federal University, Zurich, *Bulletin de la Société Suisse des Electriciens*, Vol. 47, No. 9, April 28, 1956, p. 389, 24 pp., 68 ff.)

Extra-High-Voltage Substation Isolators

A short comparative study of the types of isolator generally used in U.S.A. and Europe in extra-high-voltage systems. The horizontal-break isolator used for many years in European installations of 220 kV and above has recently lost considerable ground on the pantograph type, while the vertical-break isolator remains the American choice because of its sturdy construction, few moving parts, positive drive, fully controlled blade, and good ice and corrosion breaking ability. Moreover it is easy to adjust and to proof against radio noise and corona and is adaptable to the higher continuous currents and high momentary currents in American practice. European designs have few of these features, and require accurate stringing of their cables for proper switch contact, but even when so strung, the cables are subject to temperature changes and wind deflection. They are nevertheless more economical in first cost, ground space and steel. A vertical-break isolator, designed to combine the good features of European and American models, is

arranged in the same manner as the pantograph switch; the blade is vertical when closed and open when horizontal. It incorporates the engineering design and testing of the present vertical-break isolators while affording, at the same time, the ground and structural savings of European types. (S. C. Kilian, *Electrical World*, Vol. 145, No. 14, April 2, 1956, pp. 86/88, 9 ff.)

Grande Dixence Power Tunnel Pierced

The pressure tunnel which will convey power water from the Valdes Dix Reservoir to the Val de Bagnes above the Fionnay power station, was driven from both ends at the same time and finally pierced at the end of March. The tunnel is straight, and has a length of 9 km. and a gradient of 2 : 1,000 throughout; the excavated cross section measures 17 sq. m. in area. On the Valdes Dix side, a lateral adit 150 m. in length had to be driven. Upon its reaching the axis of the tunnel, a length of 70 m. was driven back to the initial triangulation point, following accurately the axis of the tunnel, and subsequently used as workshop and depot. At the Val de Bagnes point of attack, it was found possible to drive the access adit in the same direction as the tunnel and strictly following its axis. The article describes the measures taken to ensure accurately the direction of the drifts in accordance with calculations. Actually, the error ascertained at the point of junction of the two sections of the tunnel did not exceed 0·090 m. horizontally and 0·016 m. vertically; the actual break-through was rendered particularly difficult by the occurrence, at the very spot, of a large fault with a mass of loose rock debris. (H. Bernold, *Schweizerische Bauzeitung*, Vol. 74, No. 14, 7th April 1956, pp. 212/213, 4 ff.)

NOTE: The above-mentioned issue of *Schweizerische Bauzeitung* also includes a short article by A. Sonderegger, pp. 210/212, 4 ff., on the use of concrete spraying in tunnels, either as a rock-reinforcing agent while driving is in progress, or as permanent lining.

Fish-Handling Facilities at Mayfield Dam

Tacoma City Light engineers, working with the Washington Fisheries and Game Departments and the U.S. Fish and Wildlife Service, have developed remarkable fish-handling facilities for the 120,000 kW Mayfield dam on the Cowlitz River in western Washington. The utilities, which will cost $7 million, will include a fish ladder and tramway for upstream travel and a skimming device for downstream travel. The upstream travel will operate as follows: Flowing water in six entrances guides fish to the ladders, while a barrier dam prevents them from swimming upstream past the ladders to the spillway; after passing up the ladders, fish will move into the first of two containing pools equipped to prevent them from returning. A movable screen at the bottom of the second pool will ease fish into a hopper which will travel up the tramway at intervals to deposit them in a channel leading into Mayfield reservoir. Parr coming downstream into the reservoir will be attracted by flowing water into the skimmer device near the top of the dam. As the fish pass over a screen, much of the water will fall through the screen and be pumped back into the reservoir. The remaining flow will carry the fish to pools leading to a fish easeway which will return them to the river past the dam and power house. To compensate for possible fish losses hatcheries are to be provided. Finally, as suggested by the State Fisheries Department, siting the intake near the bottom of the reservoir will greatly reduce the possibility of fish reaching the turbines. (*Electrical World*, Vol. 145, No. 14, April 2, 1956, p. 109, 1 f.)

Roanoke Rapids Development

Very few hydro-electric schemes, even in the U.S.A., have had such a rough and protracted passage as that endured by this North Carolina venture, since the Virginia Electric and Power Company (VEPCO) bought the land for the project in 1926. Following the shelving of the plans in 1929 after the financial crash, VEPCO applied successfully for a Federal Power Commission licence as late as 1951, and then the political battle started. Finally, actual construction began about the middle of 1953, a few months after the Supreme Court had upheld FPC. The dam, built a few miles downstream of the government's huge John H. Kerr development, rises 72 ft. from the river bed; its 3,050 ft. long structure impounds 4,900 acres of water, and contains 300,000 tons of crushed stone, 800,000 bags of cement and 120,000 tons of sand. Its construction, which was completed in 2 years and 2 months, proved burdensome; for instance, the power house site, a 70 × 230 ft. excavation 72 ft. in depth, had to be blasted out of solid granite. The generating equipment consists of four 25,000 kW units. (*Electrical World*, Vol. 145, No. 15, April 9, 1956, pp. 8/9, 3 ff.)

Sakuma Project

With the completion of the Sakuma dam, Japan will have fulfilled a 20-year dream, in which most engineers had despaired. The Tenryu River thus adds 350,000 kW to the previously developed 155,000 kW. The river falls 2,400 ft. over a 100-mile stretch, and flows in flood up to 210,000 cusecs. The Sakuma site is almost halfway on the straight line between Tokyo and Osaka, the greatest load centres of the country. The dream was to build there a 504 ft. dam, only 965 ft. in crest length, which could harness a 450 ft. fall over 20 miles of river, and impound 265,000 acre-ft. of water in only 2·8 sq. miles. The granite hills of the Tenryiu Valley, the slopes of which often defy even mountain goats, made the Japanese hold back until three years ago when they decided to combine native labour with the biggest of American equipment, and called for the services of the Guy F. Atkinson Company, then completing Pine Flat dam in northern California. Actually, part of the Pine Flat construction plant was transferred to Sakuma and re-erected there, inclusive of the whole of the batching plant and the two 25 ton cableways with 8 cu. yard buckets for placing concrete. With the help of this equipment, the Japanese managed to place 6,775 cu. yards of concrete in a 24-hour period, beating the corresponding performance at Pine Flat by no less than 2,775 cu. yards. To handle the possible river flow of 210,000 cusecs, two 37 ft. diameter tunnels, each 2,200 ft. in length, provided the large diversion capacity required. The ultra-modern power plant, which houses four 128,500 h.p. vertical Francis-type turbines driving each a 93,000 kVA generator, is of an unusual design as, owing to the difficulty of levelling space in this visible-outcrop area, transformers and switchgear are set on the roof of the power house. The turbines receive water through two 23 ft. diameter pressure tunnels,

each 3,800 ft. in length, that feed four 13 ft. diameter penstocks at a bifurcation point; there is a 65 ft. diameter surge tank to each tunnel, constructed almost entirely underground to a depth of 320 ft. As the cost of building an access road to the top of the surge tanks would have been prohibitive, a 10 ton cableway was erected to transport materials and equipment up the steep rock slopes. The plan for excavating the penstocks called for a temporary access tunnel to intercept the lowest grade of the four penstock tunnels; it was sized to accommodate 12 cu. yard dump trucks. An 8 × 10 ft. shaft was then driven upward along the inverts of the four penstocks, and headings were driven from the bifurcation chamber, the muck dropping through the inclined shaft directly into waiting dump trucks. The steel lining sections were lowered into the tunnels from the bifurcation chamber and welded together in place. It is expected that the plant will go on the line by midsummer, when the reservoir should reach high water level. (McGraw-Hill World News, Tokyo Bureau, *Engineering News-Record*, Vol. 156, No. 16, April 19, 1956, p. 38, 6 pp., 9 ff.)

NOTE: A short article on Sakuma Dam also appears in *Electrical World*, Vol. 145, No. 15, April 9, 1956, p. 15, 1 f.

Determining the Course of an Open Channel

While the influence of the cross section and longitudinal section of an open channel on the flow has been elucidated to a wide extent, our knowledge of the effects of bends is still rather scanty. In this paper, the author makes suggestions as to how bends in open channels should be designed and laid out with a view to disturbing as little as possible the normal flow of a straight stretch, or, in other words, to reducing to a minimum flow losses in bends. Separation, which is the main source of flow losses in bends, can be substantially checked or prevented by laying out the banks according to a hyperbolic curve involving a widening of the cross section at the crown of the curve to 1·3 times the normal width, and by giving a moderate slope to the off bank and a steep slope to the near bank. In instances where several consecutive bends occur, the insertion between such curves of short straight sections equal in length to, or double, the width of the channel, favourably affects the flow. In streams in which the bottom of the bed is subject to alterations, this kind of layout not only reduces energy losses but also inequalities in the cross section and longitudinal section. (Dr.-Ing. Günther Garbrecht, *Die Wasserwirtschaft*, Vol. 46, No. 6, March 1956, p. 151, 5 pp., 9 ff.)

Undeveloped Water Power in Liberia

This is a detailed report on the tour of investigation undertaken by the author at the head of a team of German engineers at the request of the Liberian Government, to assess the possibilities of harnessing the water resources available to power generation. The five major rivers—Mano, Loffa, St. Paul, St. John and Cestos—all rise in French Guinea and reach Liberian territory at 300 to 600 m. above the level of the Atlantic Ocean. Yearly precipitations vary between 4,000 and 5,000 mm. in the coastal strip and decrease inland to between 1,200 and 1,500 mm. Following a comprehensive study of hydrological and meteorological conditions in the country, the following rivers were surveyed: Loffa and its tributary Maher, St. Paul and its tributary Du, Farmington, throughout a Liberian watercourse, and St. John. The main consumption centre of electric energy is the triangle formed by the capital, Monrovia, the Bomi Hills, 70 km. to the north, and the town of Kakata about 55 km. to the north east. The investigations made within a radius of 100 km. from Monrovia show that only two developments are economically possible: a storage plant on the Du, and a run-of-river plant on the St. Paul. The two preliminary projects, which assess yearly production at 40 to 50 million and 95 million kWh respectively, are briefly described. No decision has been reached as to which scheme should have the priority, it is however expected that the question will be settled in the very near future since Liberia has a vital interest in harnessing the power resources of its own waters instead of being restricted to expensive imports of diesel oil. So far, the only hydro-electric development in operation in Liberia is the 3,000 kW Farmington run-of-river plant, owned and run by the Firestone concern in conjunction with 800 sq km. of rubber plantations. (Dipl.-Ing. Fritz Bassler, Freiburg, *Die Wasserwirtschaft*, Vol. 46, No. 6, March 1956, p. 141, 8 pp., 14 ff.)

Concrete-Faced Spillway Washed Away

Heavy spring run-off waters breached a 38 ft. concrete-faced overflow spillway on the Battle River near Forestburg, Alberta, washing away 3,000 cu. yards of reinforced concrete and much greater quantities of earthfill. The estimated damage was $350,000. The break occurred at 10 a.m. on April 22, eighteen hours after a labour foreman discovered a small hole in the downstream face. Apparently, increasing amounts of water flowed through the original hole, washing away progressively greater amounts of earthfill until the concrete facing collapsed. The cause of the original hole has not been determined, but investigators believe a break occurred in a bypass pipe through the dam. The possibility that allowable stresses were exceeded has been discounted since the spillway was designed for 15,000 cusecs and the estimated flow at failure was 3,800 cusecs. The spillway is part of an earthfill dam which was built to impound cooling water for a near-by thermal power plant under construction by Canadian Utilities Ltd. It is hoped that the damage will have been made good by mid-August to start power generation in September as scheduled. (*Engineering News-Record*, Vol. 156, No. 19, May 10, 1956, p. 29, 1 f.)

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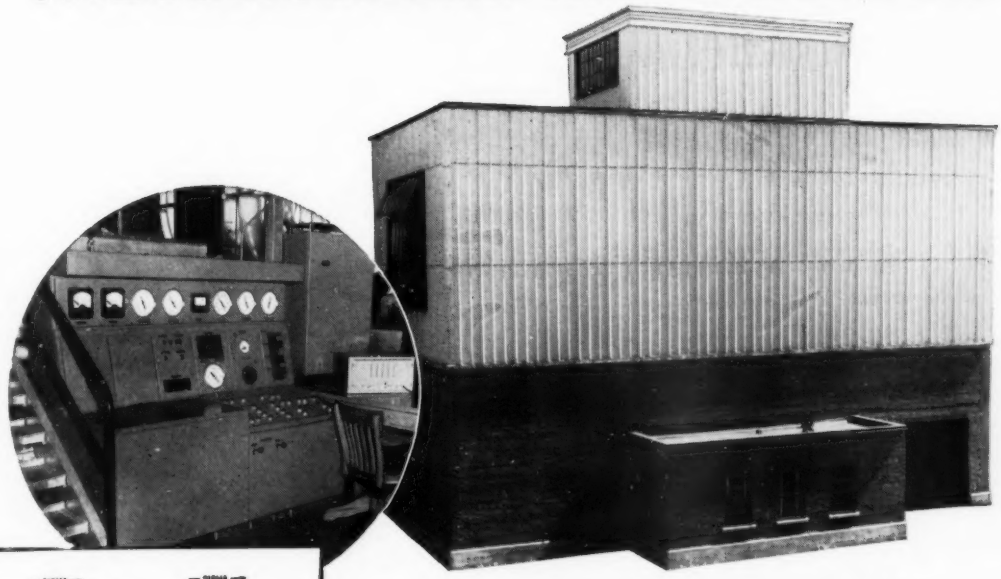

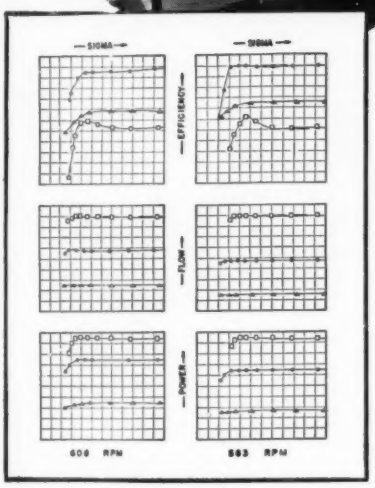

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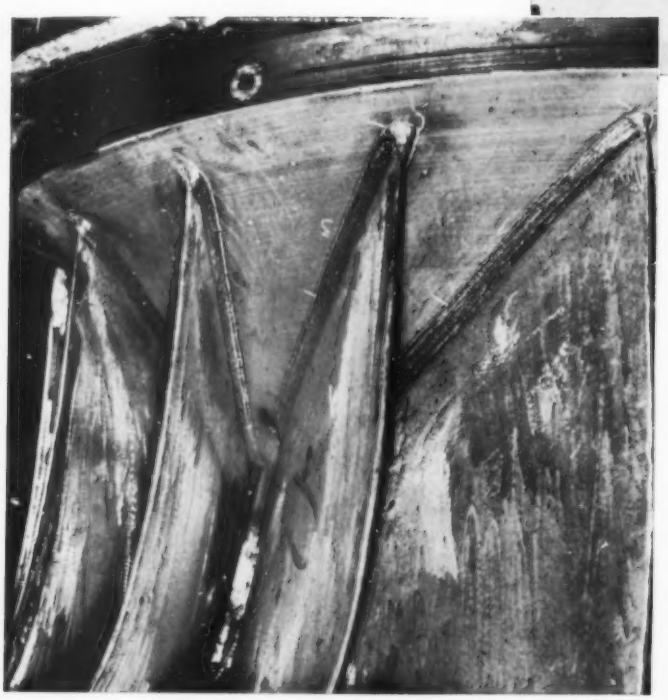
Modern construction of Francis runners

The runner shown on these pictures is of *welded* construction with blades and rim of stainless steel (Chromium 13%) and hub of plain carbon steel. The welding is effected according to a new, simple method using electrical induction for the necessary pre-heating. On this runner the welding results have been most successful.

Welded joints before final grinding.



Our normal design of *welded* Francis runners

KMW also manufacture Francis runners of welded construction according to their patented method. In this case the runners are made of plain carbon steel with only those parts which may be exposed to cavitation damage coated with corrosion resistant material. The coating is effected in a simple and reliable way before welding the various parts together. By this means the manufacturing costs are appreciably reduced.

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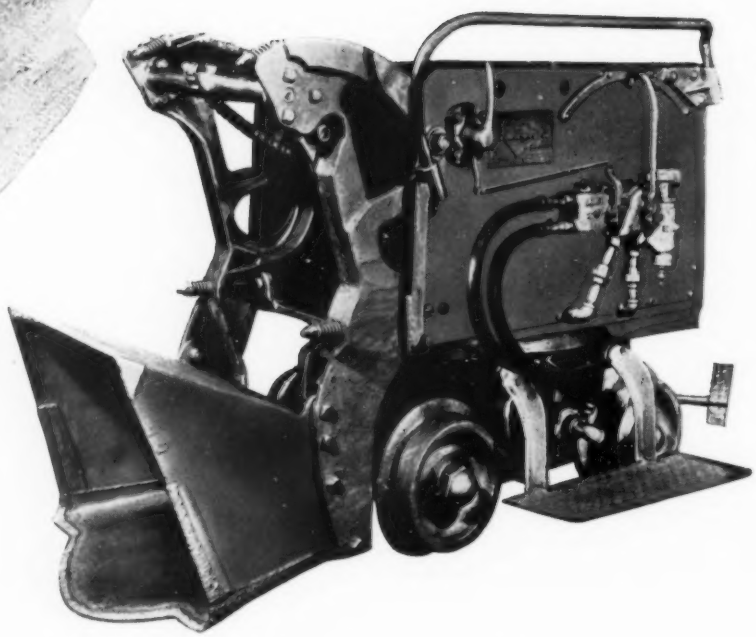

South Africa achieves

A NEW WORLD TUNNELLING RECORD

Doornfontein, gold and potential uranium producer, on the West Wits line, has established a new world tunnelling record. Using a model 21 Eimco loader a total of 1,508 ft. was advanced in 26 days ended March 27.

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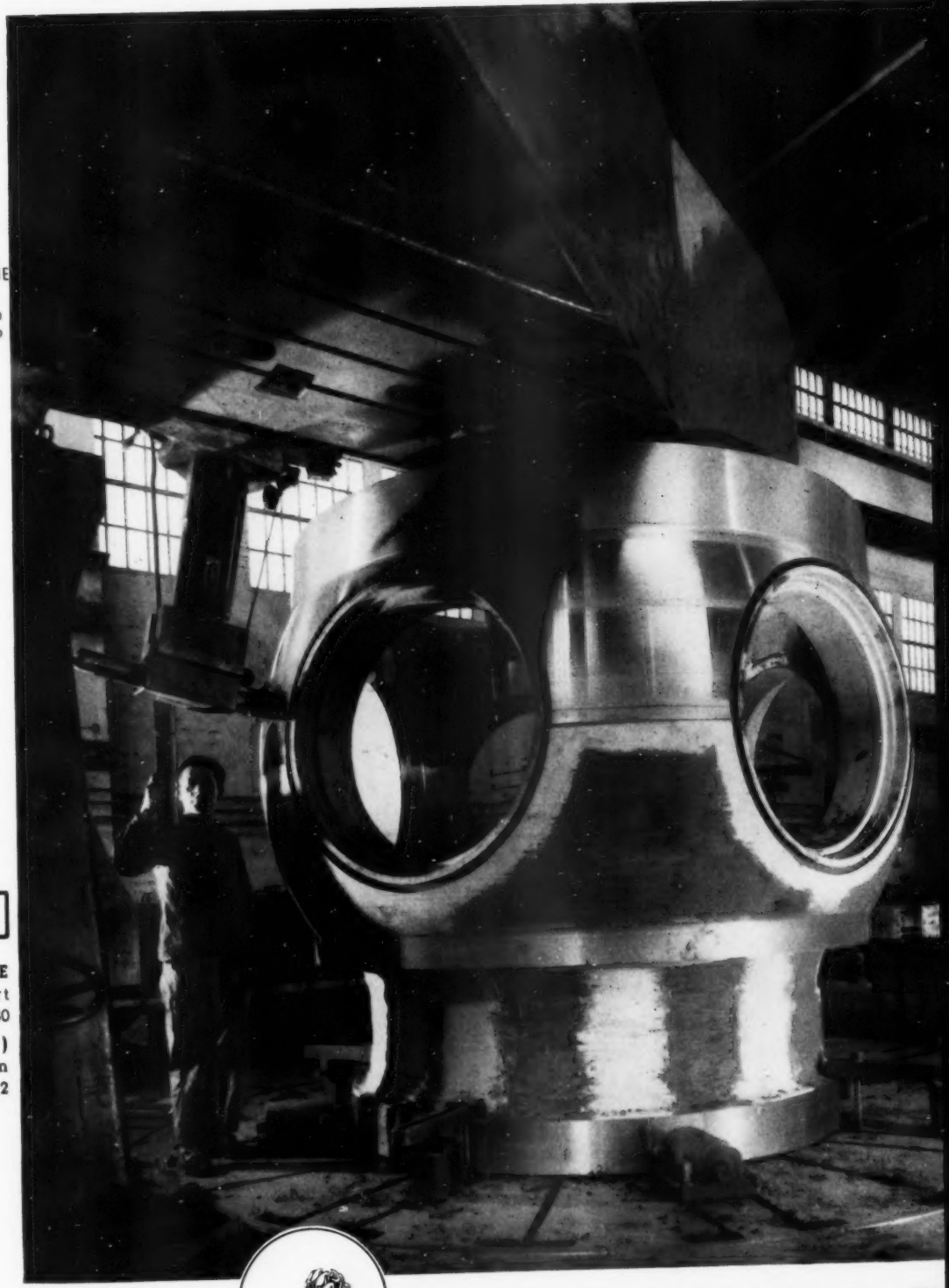

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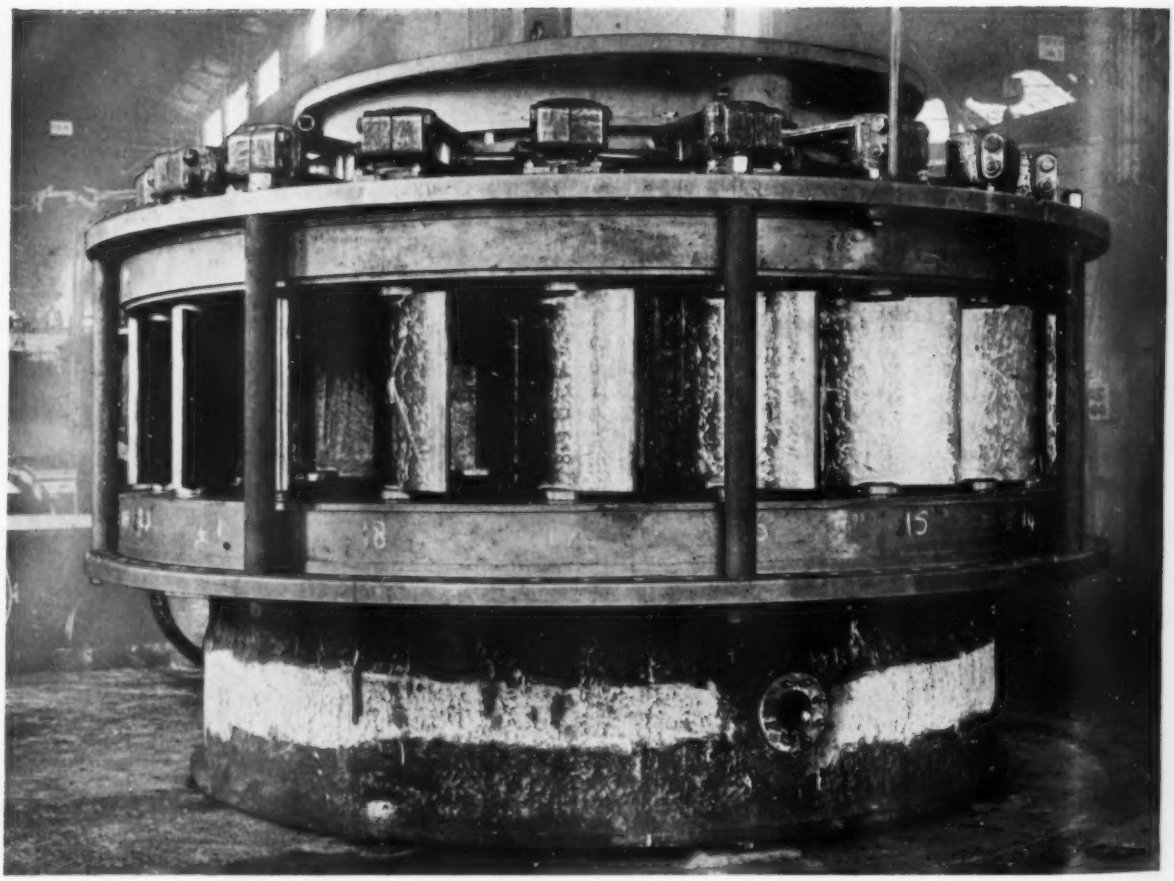

Upper and lower casings with deflector vanes and operating mechanisms.

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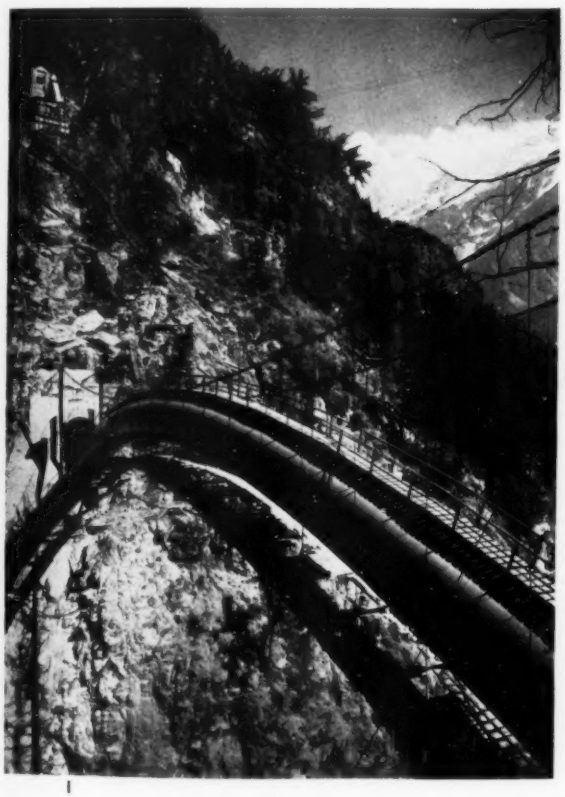

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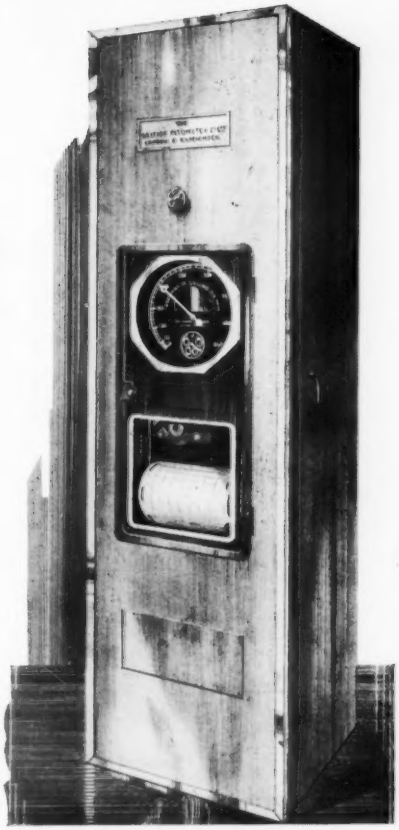

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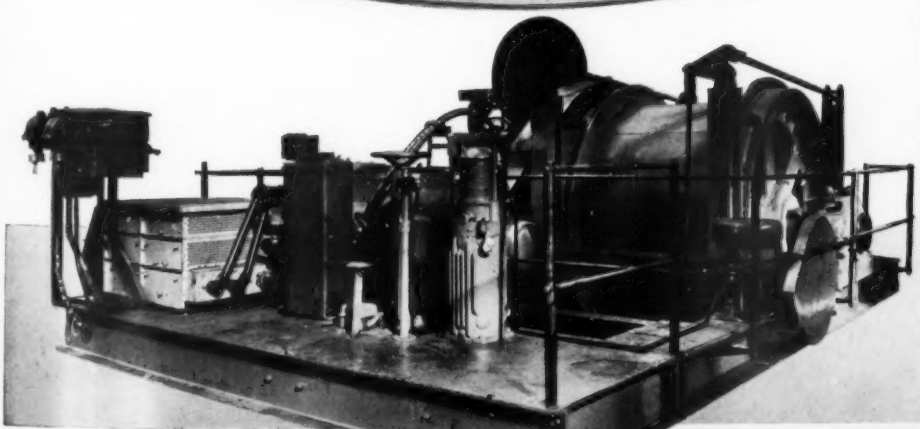

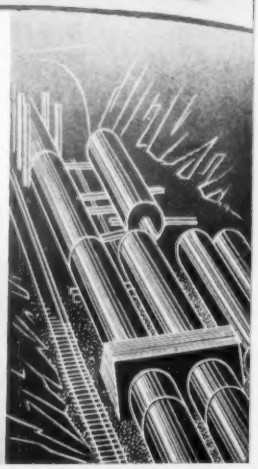

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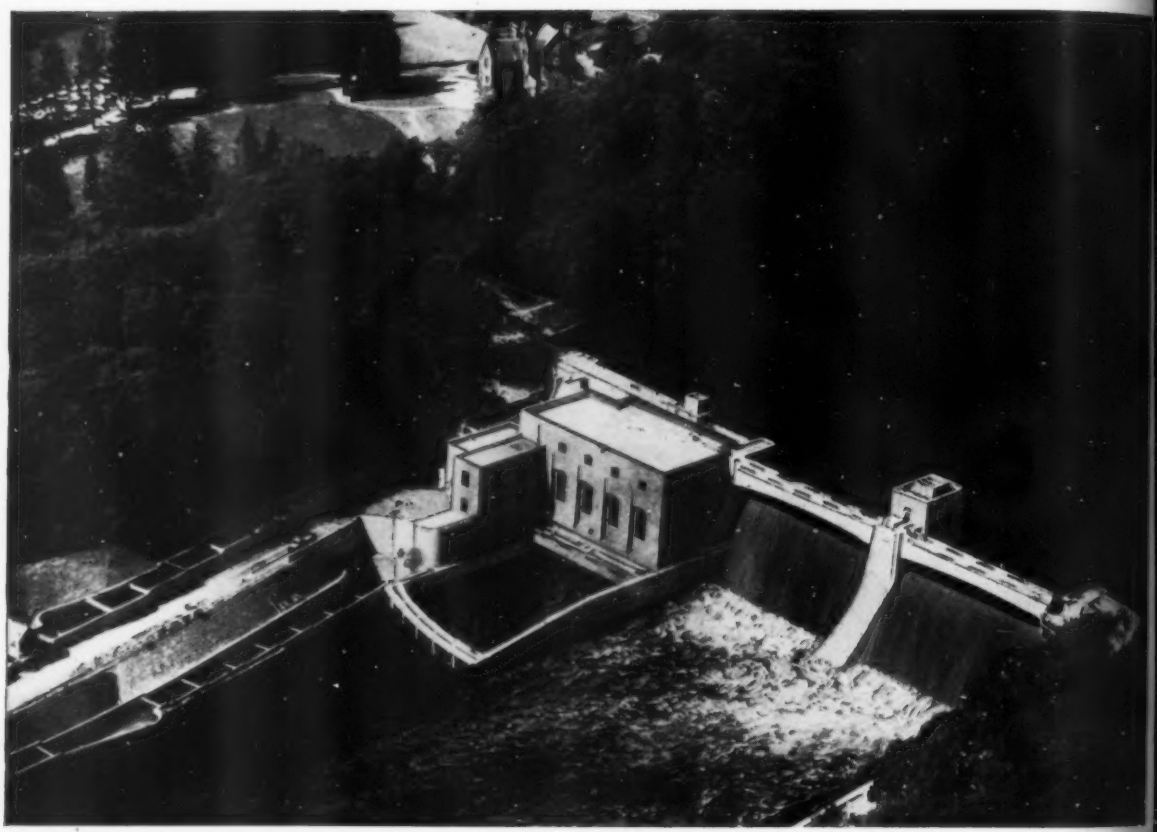

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